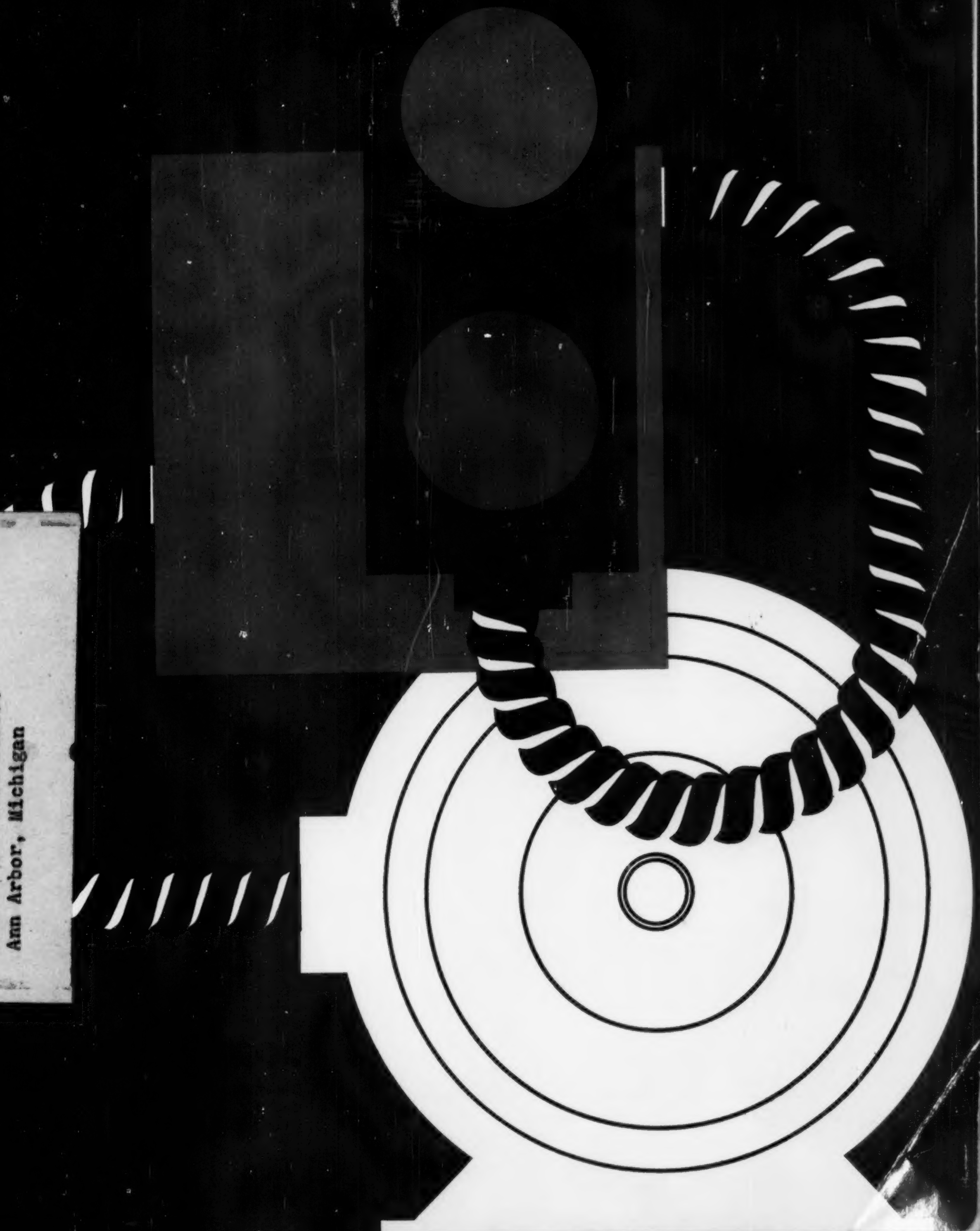
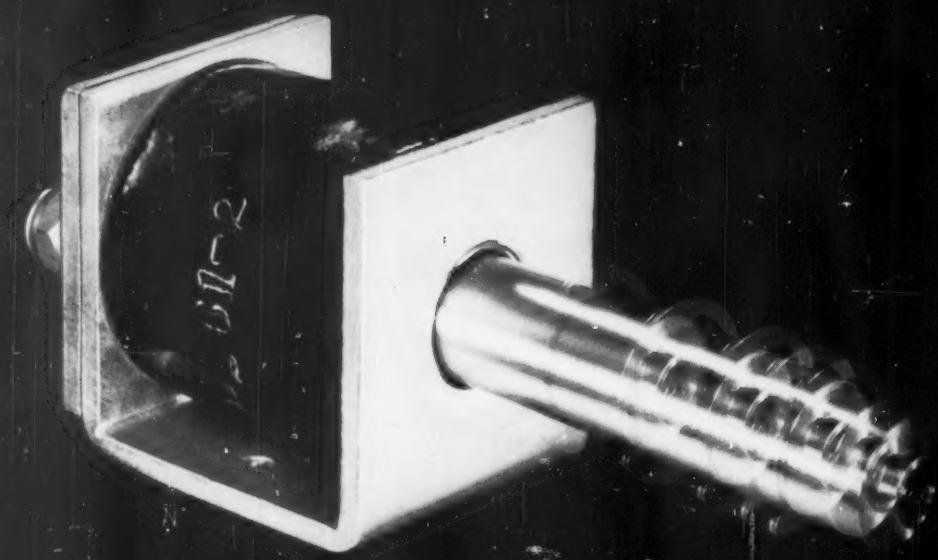
MACHINE DESIGN



100 MILLION OPERATIONS!



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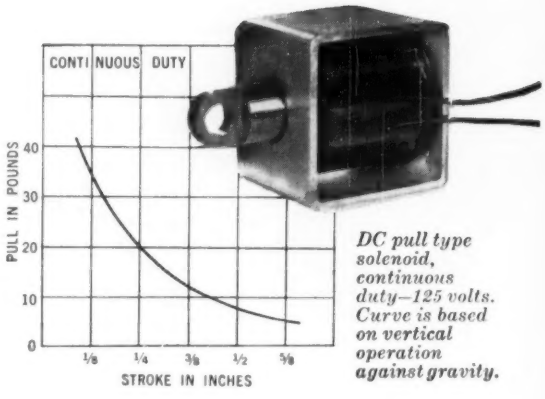

DC pull type solenoid, continuous duty—125 volts. Curve is based on vertical operation against gravity.

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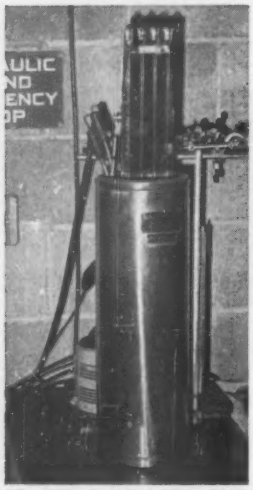
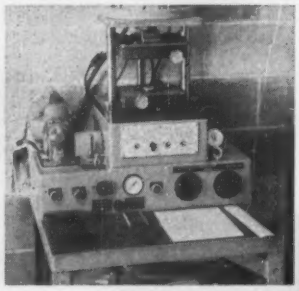
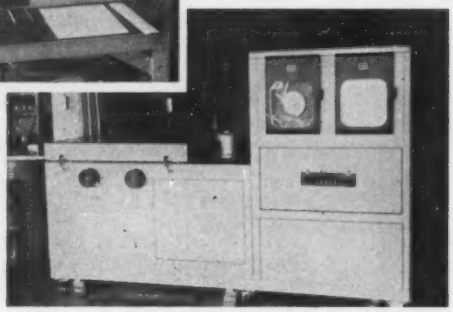


TEMPERATURE RETRACTION TESTER

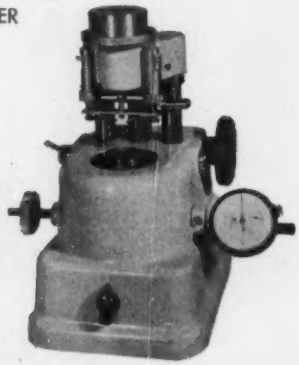


VISCOMETER



ENVIRONMENTAL TEMPERATURE TESTER

MICRO HARDNESS TESTER



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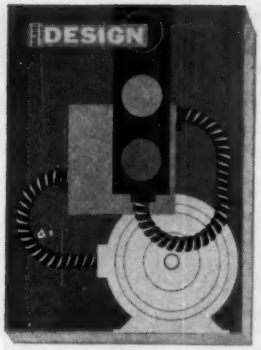

Front Cover: Basic elements of a complete ac motor-control system appear ready for action in artist George Farnsworth's cover design. Authors J. R. Wickey and A. S. Newman Jr. get this subject off to a controlled start in their article series which begins on Page 100.

December 22, 1960

CONTINUED NEXT PAGE

THE PROFESSIONAL JOURNAL FOR ENGINEERS & DESIGNERS

MACHINE DESIGN

December 22, 1960
Volume 32 — No. 26

IN THE NEXT ISSUE: Value engineering . . . Eli Whitney's uniformity system . . . fillet rolling . . . mechanism design . . . across-the-line starting of motors . . . twin-head capstan . . . high-strength structural adhesives . . . hole-position tolerances.

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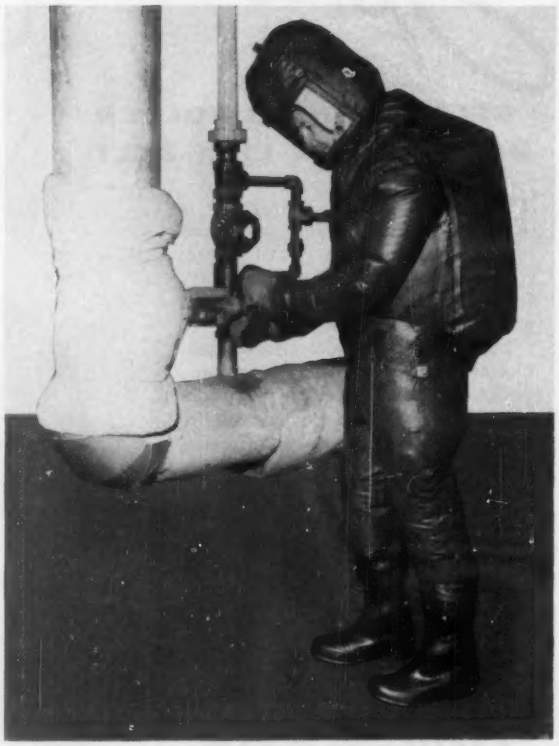
Ready-to-Wear for Hostile Environments

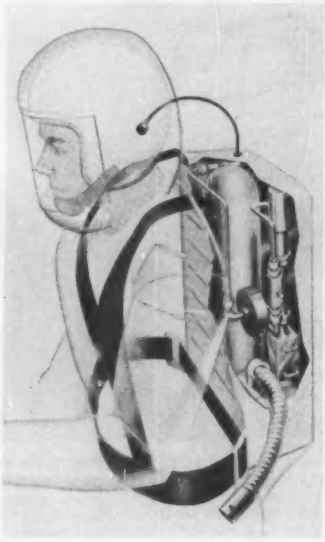
WHEN man finally makes a landing on another inhabited planet, he may well resemble a creature out of his own science fiction. In any case, the protective clothing he will undoubtedly be required to wear will give the foreign reception committee a misleading first impression.

A practical earthbound version of suit-type environmental systems, and a major advance insofar as weight and operation are concerned, is a system conceived by AiResearch Mfg. Div., Garrett Corp. Designed originally for use in handling toxic missile fuels, the suit provides protection against a wide range of hostile down-to-earth environments: Chemical processing, firefighting, nuclear plants, etc. Made as two separate components, it consists of the plumbing, or life-support system, which straps on the back and weighs a mere 17 lb, and the protective suit. (Tailored for space work, a "Moon Pack" version weighs 50 lb.)

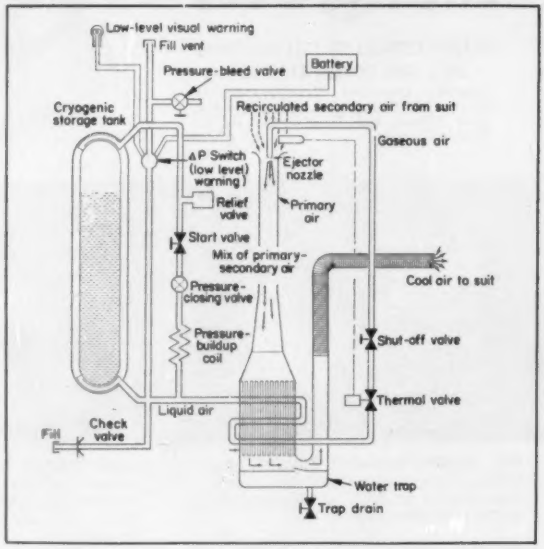
Basic hardware in the backpack consists of a cylindrical cryogenic air-storage vessel (for breathing air), a quantity gauge, ejector for circulating the air, heat exchanger for cooling the recirculated air, and a trap for collecting solids and entrained water.

In terms of ventilation, cooling, and humidity, the unit provides a completely self-sustained, habitable atmosphere for its occupant. Sufficient liquid air is provided to support one man for two hours before recharging is required.





Knapsack full of plumbing comprises the life-support system in the AiResearch suit. Since vaporization of liquid air provides necessary working pressures, no external source of power is needed and the closed system contains no moving parts.



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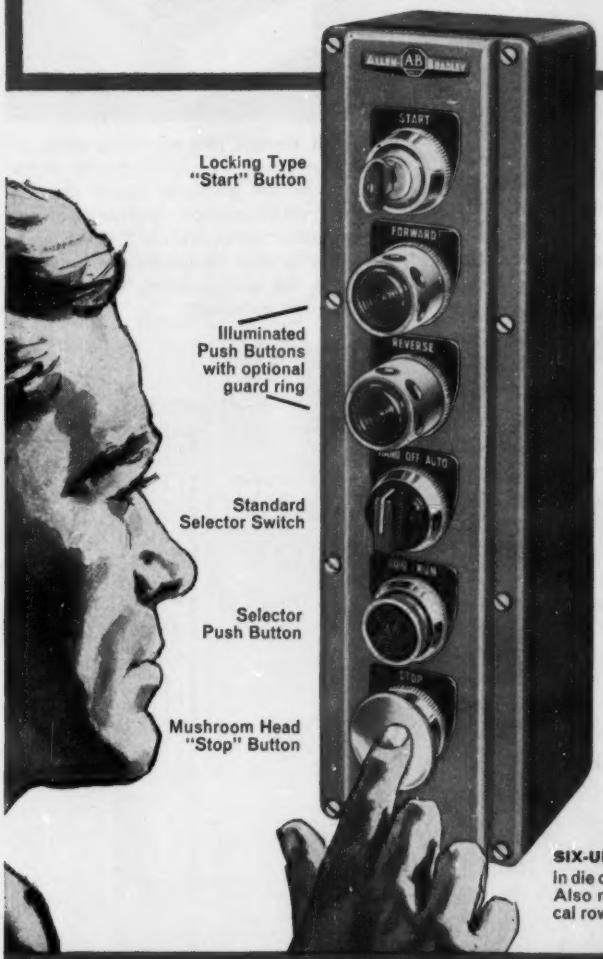

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Selector Push Button

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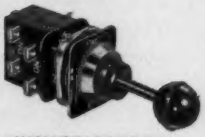

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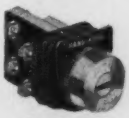

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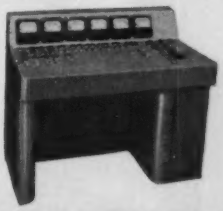

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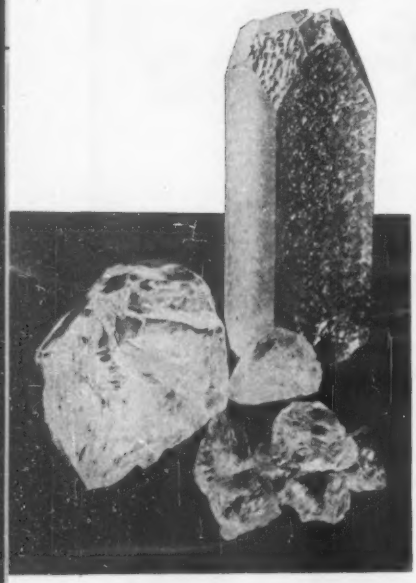
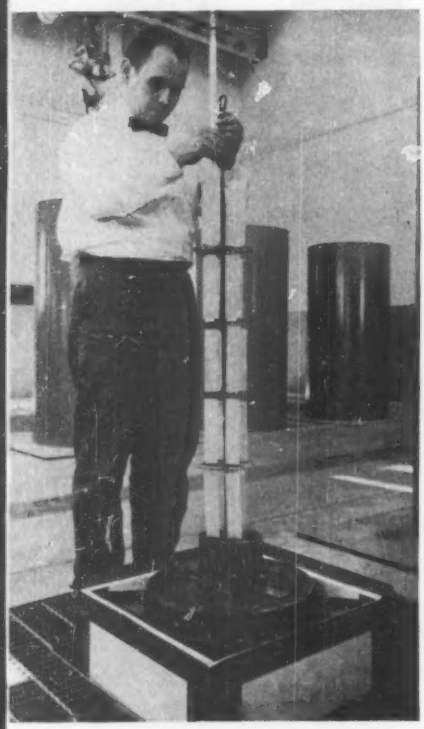
Hot-House Quartz

Production-Line Harvests of Near-Perfect Synthetic Crystals Will Widen Use in Electronics



Perfect synthetic quartz crystals above (rough natural variety in foreground) contain no foreign inclusions, are easily oriented for slicing into electronic-component form. Seed crystals (being lowered into tank, below) will grow to full size after three weeks at 700-F heat, 25,000-psi pressure. Seed crystals are either natural or artificial.



NORTH ANDOVER, MASS.—A 50-year bottleneck in the supply of communications-quality quartz has been broken by Western Electric Co. Nearly perfect crystals are being grown in mass-production lots at the Merrimack Valley Works of the Bell System manufacturing arm.

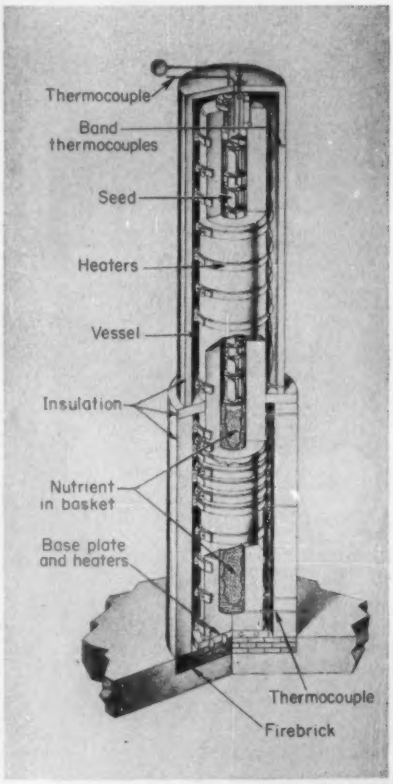
Based on a heat-and-pressure process developed by Bell Laboratories, the new "crystal-farm" technique turns out artificial crystals at a fraction of the cost of the natural variety.

In telephone work, quartz crystals form the heart of equipment that carries many different conversations simultaneously on a single circuit without interference. Quartz is also used for regulating radio frequencies and generating ultrasonic waves. The low-cost synthetic "gems" may open new applications where quartz will replace other circuit elements.

Although quartz is the world's most common mineral, paradoxially, the pure crystals required for communications have cost about $30 a pound in the natural state. Chief source was the interior of Brazil, where mining was done on an unstable free-lance basis. Cost of processed communications-grade quartz plate ran closer to $1500 a pound after losses (up to 97 per cent) were deducted for crystal imperfections and slicing waste.

While the problem of making suitable synthetic crystals has been under attack for half a century, the first production-oriented pilot plant was built by Western Electric in 1958. Basis of the process was a hydrothermal technique developed in experimental form by Bell Laboratories. The final production facility—built after considerable development work on pressure-vessel closures—will turn out artificial crystals with a yield per pound 250 per cent that of natural quartz.

String of crystals (above) forms when inexpensive pieces of natural quartz at the bottom of the pressure vessel dissolve into hot alkali solution, re-deposit on the seed plates. Strip heaters (below) maintain the needed temperature differential between the cool growing end and the hot nutrient zone.



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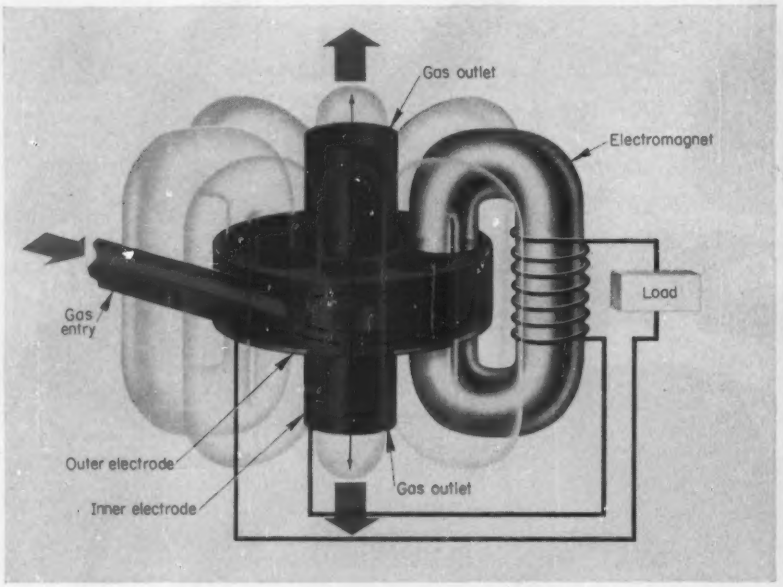
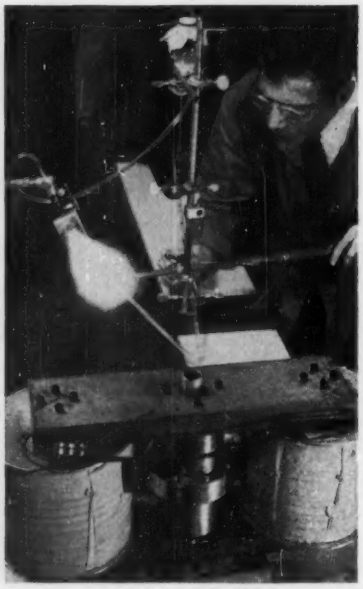




Schematic diagram shows how the gas stream bends, developing a vortex action. By eliminating the linear gas channel normally found in MHD devices, Tapco engineers were able to significantly decrease size and specific weight of the device. Plasma, right, adjusted to 5000 F, provides the electrical conductor. The high-temperature plasma is obtained from combustion of hydrogen and oxygen. Its electrical conductivity is enhanced by an alkali-metal additive.

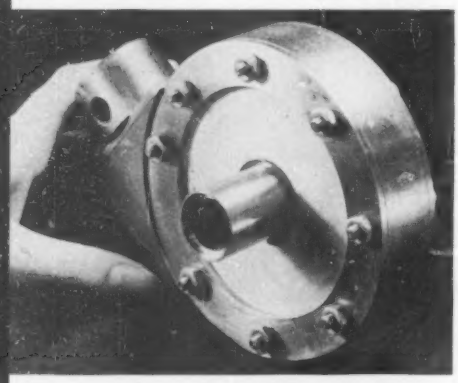
A 5000-F plasma vortex holds the potential for

One Kilowatt per Pound

COMPACT magnetohydrodynamic generators may soon rival fuel cells and thermoelectric sources as practical producers of power. A new type MHD unit, conceived by researchers at Thompson Ramo Wooldridge Inc., Tapco Group, Cleveland, is now in an advanced development phase. The unit is furnishing design data for lightweight generators with outputs ranging from a few kw on up.

The new device, called a Vortex MHD Generator, channels gas streams in spiral paths, rather than letting them flow horizontally through a tube. The design, according to Tapco engineers, provides highly efficient use of the magnetic materials needed in an MHD unit and gives an outstanding power-to-weight ratio.

It's too early to anticipate all the possible applications for the new unit, but one of the most obvious is as a source of emergency power in manned space vehicles. A one megawatt space plant, says Robert T. Craig, Tapco project manager, might be developed having a specific weight on the order of one pound per kw. This figure includes weight of the heat source—a specially compounded solid-rocket fuel. The specific weight figure quoted is nearly ten times less than other electrical-power sources suitable for emergency service in space.



Laboratory model of the Vortex MHD Generator is designed to produce one to ten kilowatts of electrical power. Part of the output is fed to the load, part to electromagnets (not shown) spaced around the device.

An MHD generator produces power somewhat like an electric generator, wherein a conductor moves in a magnetic field. However, in the MHD unit, the conductor is a gas, not a wire. The gas, "seeded" with potassium, cesium, or one of several other alkali metals to give it adequate electrical conductivity, is ionized by raising its temperature to 4000-5000 F.

In the generator, the hot ionized gas travels through a magnetic field (applied at right angles to the flow). Free electrons "in solution" are deflected by the field and make their way to the anode. An electric current is produced as electrons move from the anode, through the load, and back to the cathode. From there, electrons return to the gas.

Voltage at the terminals of an MHD generator is directly proportional to magnetic-field intensity, gas velocity, and distance between electrodes. The generator supplies maximum power when the voltage drop across the load is half the circuit voltage, but resistance losses are high under these conditions.

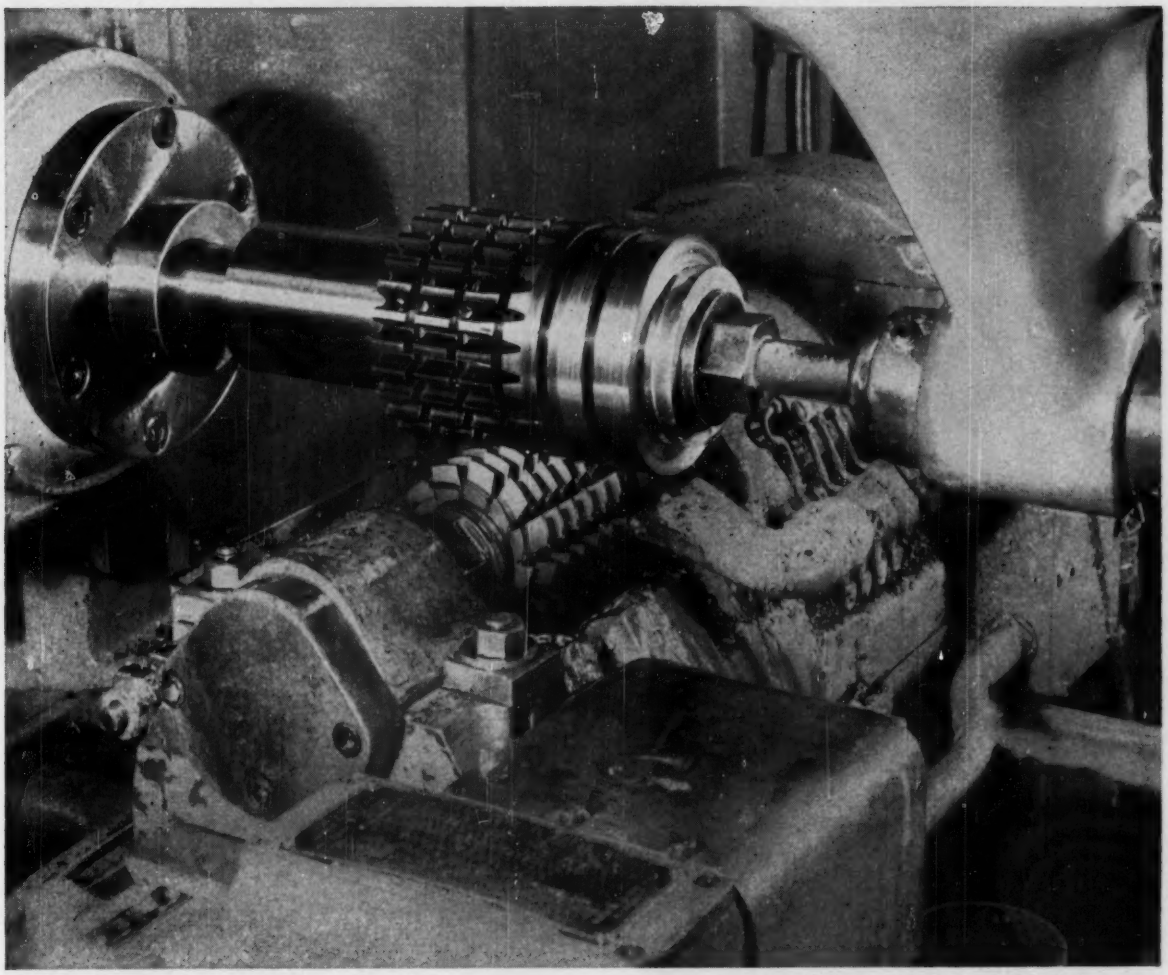


Photo courtesy Chelsea Products, Inc.

Aristoloy Leaded Steel provides free machining for Chelsea Products, Inc.

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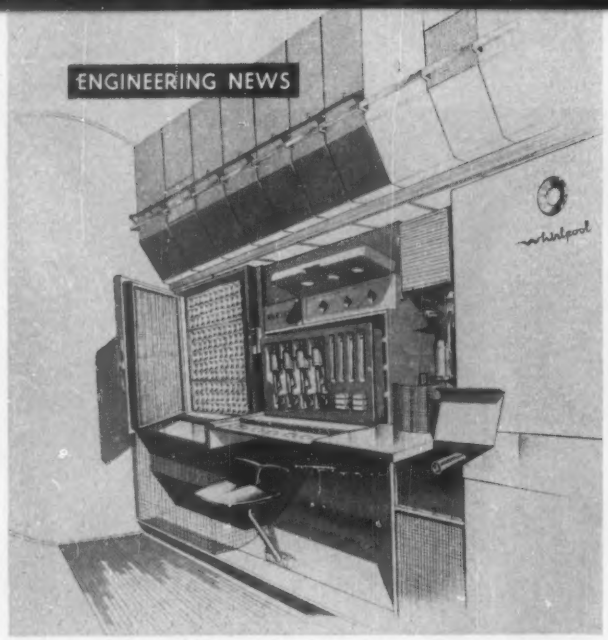
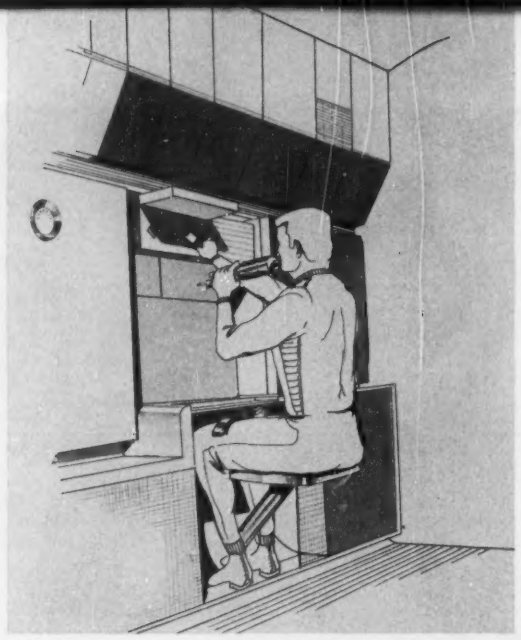




One spaceman will eat at a time. After heating his canned meal in the oven (which brings it to 175 F within 30 min), the astronaut uses a ratchet-squeezing device to crank out dinner.

Design for Zero-G Dining

Force Feeding Is the Style In New Space Kitchen

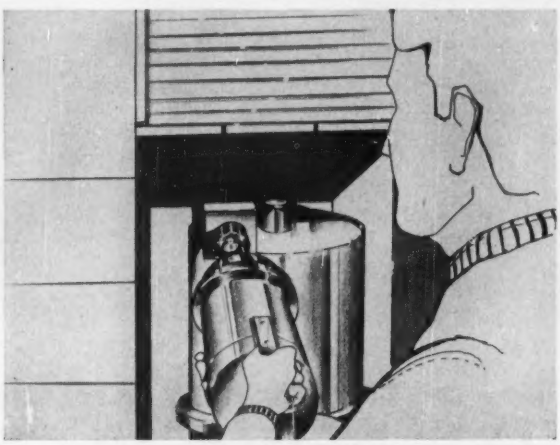
ALL meals for sustaining a three-man space team on a 14-day mission will come out of a tiny kitchen now being designed by Whirlpool Corp., St. Joseph, Mich. Tailored to a volume of less than 450 cu ft (7.5 ft diam by 10 ft long), the kitchen will house a thermoelectric refrigerator and freezer, a three-cavity oven, and a 2½ gal water system. None of these appliances will operate like their earthly counterparts.

"During space flight, men and equipment will be weightless, and this zero-gravity problem has greatly influenced design of the kitchen," says Howard Brehm, project co-ordinator. No meals will be cooked in space; rather, they will be prepackaged and possibly dehydrated. Most foods will be loaded in disposable containers that resemble over-size toothpaste tubes.

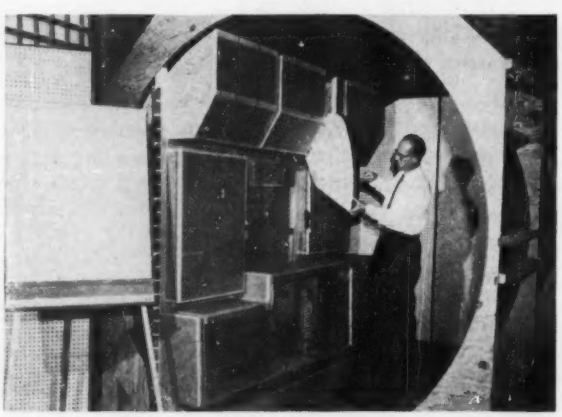
Because water won't flow (even *downhill*) at zero gravity, Whirlpool engineers have included a manually operated positive-displacement pump. Operating in an air-free water system, the pump will meter out a preselected amount of cold water when the space crewman works its handle (manually) while holding on to a support bar with the other hand. (If he didn't hold on, he would push himself across the kitchen each time he tried to operate the handle.)

Another useful gadget not found around normal kitchens is a device that resembles a squeeze-type potato masher. After warming up canned foods (in the oven), the spaceman will add a mouthpiece to the can, then insert the can in the "masher." Squeeze pressure will force the canned food out of the container into the astronaut's mouth.

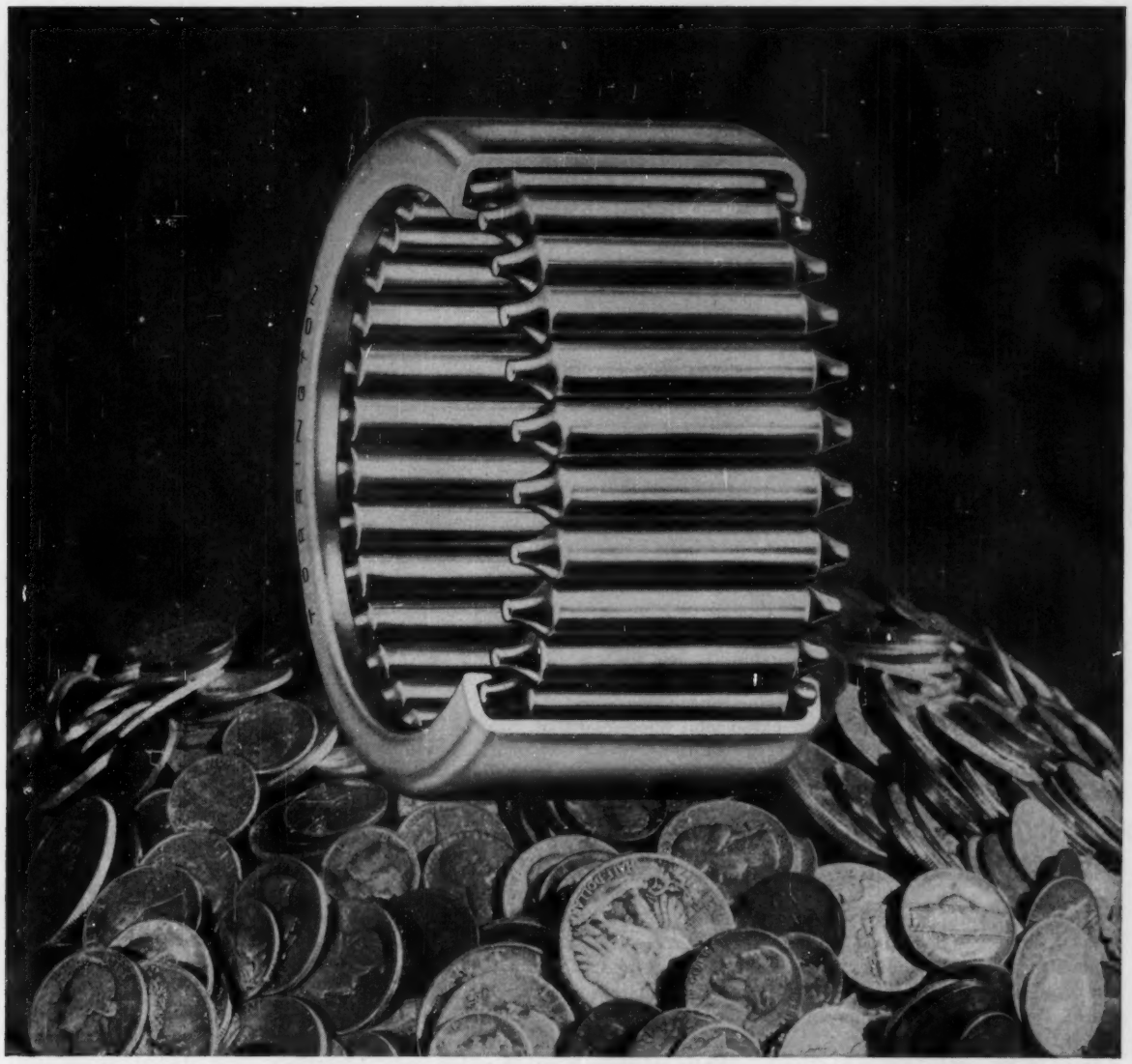
Last step before dining in space involves snapping the tubes or other food items into holders on a tray. The tray and the diner will also be clamped down.



Water transfer tank, used to reclaim water from the recovery unit, must be kept air-free. At zero gravity, air bubbles don't rise; they stay in solution and mingle with the water.



Full-size mockup of the kitchen was put together to check out critical dimensions. Opened cabinet will contain dry food.



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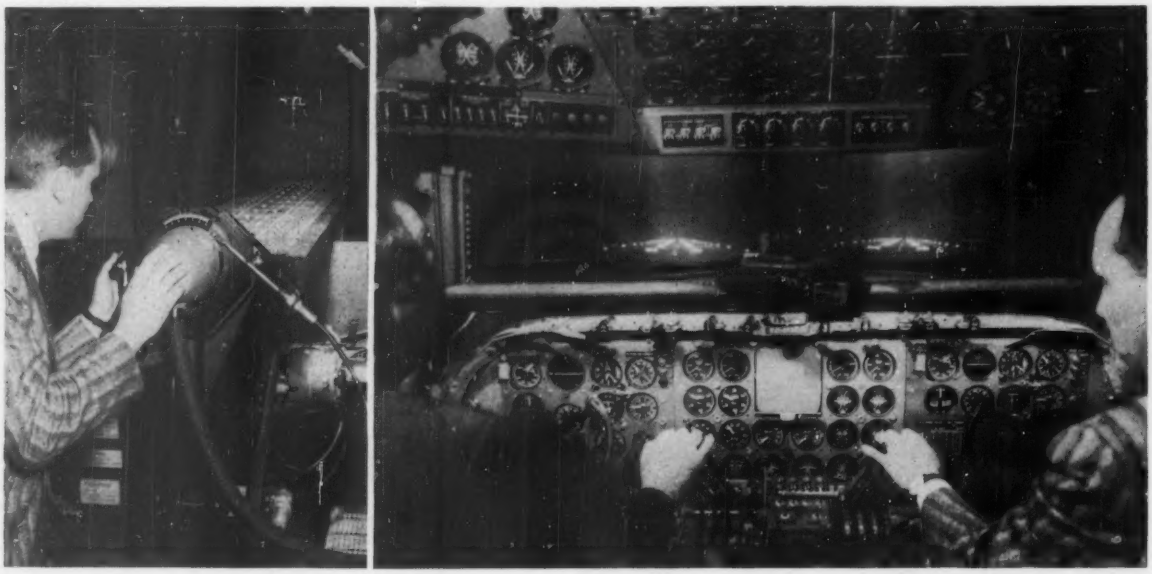


Low Ceiling in the Hangar

Restricted visibility is artificial, but realistic, in a new IFR training device for airline pilots. Used by United Airlines in conjunction with its DC-6B electronic simulator, the equipment consists of a closed-circuit TV system and a revolving belt on which runway lights are depicted with fluorescent paint. The belt is equivalent to 7000 ft of runway with 2000 ft of approach lighting. Moving at the relative speed at which the flight simulator is "flying," the belt passes in front of a TV camera. Light patterns—activated by ultraviolet rays focused on the fluorescent paint—are picked up by the camera, and the image is transmitted to the screens of two 27-inch TV monitors placed at each side of the simulator windshield. The device is manufactured by the Dalto Corporation of Norwood, N. J.

MGD Engine Set for Prototype Stage . . . May Challenge Space

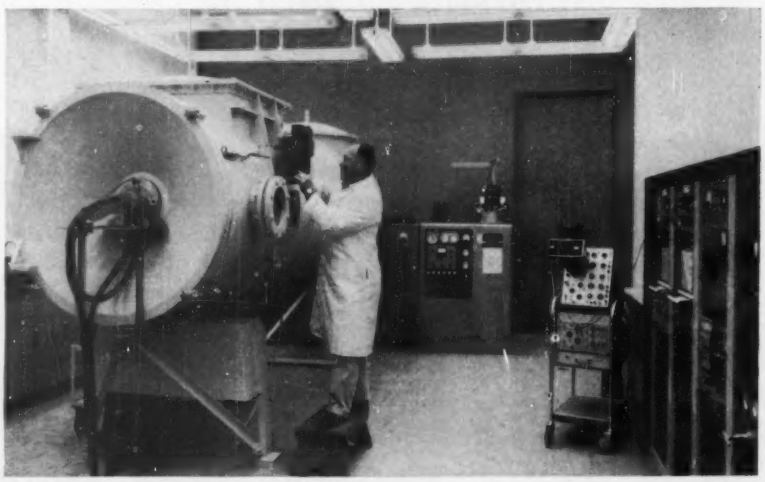
HAWTHORNE, CALIF. — First direct measurement of continuous thrust from a magnetogasdynamics engine, forerunner of a type that may propel manned vehicles during interplanetary flight, is being attained in the Advanced Research Center at Norair Div., Northrop Corp.

In the few other MGD engines in existence, only indirect indications of thrust are obtained, usually with jet vanes or pressure probes. The Northrop technique involves the use of a three-degree-of-freedom thrust balance and strain gages.

Northrop's MGD engine uses ionized nitrogen as the propulsive fluid. The plasma is injected into a 20-ft vacuum tank at an initial speed of 16,000 fps. As it enters the chamber, the plasma is directed into a region of crossed electric and magnetic fields where it is accelerated to an equivalent velocity of 40,000 fps. Measurements of the reaction forces have shown thrust levels on the order of 2 lb, maintained for as long as one minute. Thrusts of 5 to 500 lb will be produced by refined models of the engine, according to Northrop scientists.

Present plans for the engine call for its installation in an interplanetary vehicle which would first be put into orbit around the earth. While orbiting, it would collect and store air to be used as the reaction mass for interplanetary travel. Power requirements for the engine—high in terms of electrical energy—would be met by a nuclear reactor.

A prototype model of the engine is being designed now, according to Northrop, and design details will be submitted to the government.



Plasma wind tunnel houses the MGD engine during full-scale runups. Engine has produced 2 lb of thrust at specific impulse of 1200 lb per sec.

Topics

Big wheels for small cars are offered by Buick. Optional equipment for the Special series includes 15-in. wheels instead of the standard 13-in. ones. With the larger wheel, the Special's ground clearance is the same as the regular-size Buick's.

• • •

Really LP, a tape recorder built in Great Britain plays or records for 40 hours. Developed at the request of an airline that wanted to entertain passengers on long flights, the Paraphone weighs 35 lb and measures 14 by 14 by 12 in. A 1200-ft, inch-wide tape plays one hour per track; a two-track head on a cam assembly, with 20 positions for each of the heads, makes possible the 40-hour performance.

• • •

Fuel cells join fossils in exhibits at the Smithsonian Institution. Allis-Chalmers has given the museum the first vehicle to be powered by electricity developed in fuel cells—a tractor built about a year ago. Electricity for a 20-hp motor that powers the tractor comes from 1008 individual cells. The tractor has demonstrated its ability to develop more than 3000 lb of drawbar pull, enough to pull a multiple-bottom plow.

• • •

Doll with a heart, or at least a heartbeat, is the by-product of research on the electric watch at Hamilton Watch Co. The mechanism includes a balance wheel and a rod that vibrates a diaphragm to make a sound like a heart beat. The organ will thump away in Dolly's sawdust for six months on one set of small batteries.

• • •

Slot machine for shutterbugs dispenses supplies and provides service. A new vending machine offers a selection of 18 types of film and flash bulbs and will also accept exposed film for processing.

• • •

Something new under the sea is a "floundering disc" marine propeller invented by Dr. Peter Schlumbohm of New York. Instead of having conventional blades, this propeller is flat and circular. It is also flexible, and it continuously deforms and reforms as it revolves, thereby producing thrust. Two stationary plates, located above and below the disc, create a vacuum which twists the propeller to make it function (more or less).

Circle 411 on Page 19

Reader Information Service

SUBJECT INDEX

Editorial and Advertising content classified by subject and listed by page number for convenience when studying specific design problems. For further information on subjects advertised, refer to advertisement and circle Item Number on a Yellow Card—following page.

MACHINE DESIGN is indexed in the Applied Science & Technology Index and the Engineering Index, available in libraries, generally. Microfilm copies are available from University Microfilms, 313 N. First St., Ann Arbor, Mich.

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Index to New Parts & Helpful Literature

BY ITEM NUMBERS

HELPFUL LITERATURE—descriptions start on page 148

NEW PARTS & ENGINEERING EQUIPMENT—descriptions start on page 152

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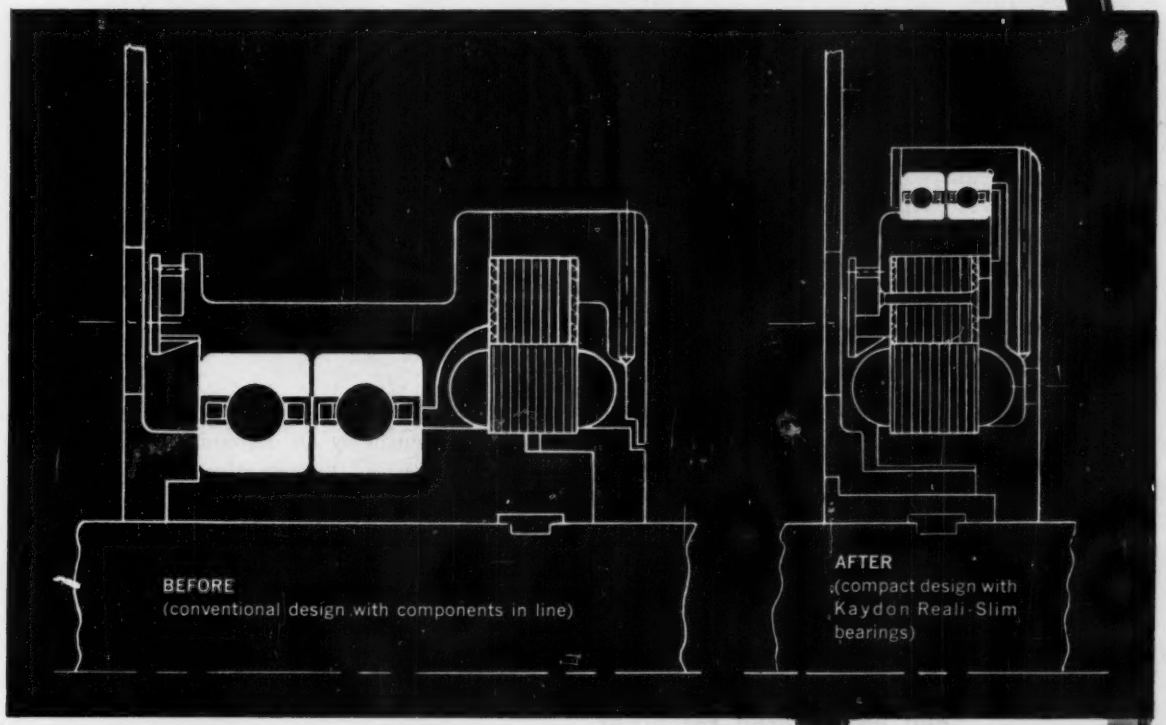
Don't let in-line design get in the way of a compact product...

"NEST" COMPONENTS INSIDE THE BEARING BORE



Motor assembly redesign shown above is typical of the way Kaydon Reali-Slim bearings save space, reduce weight, cut costs!

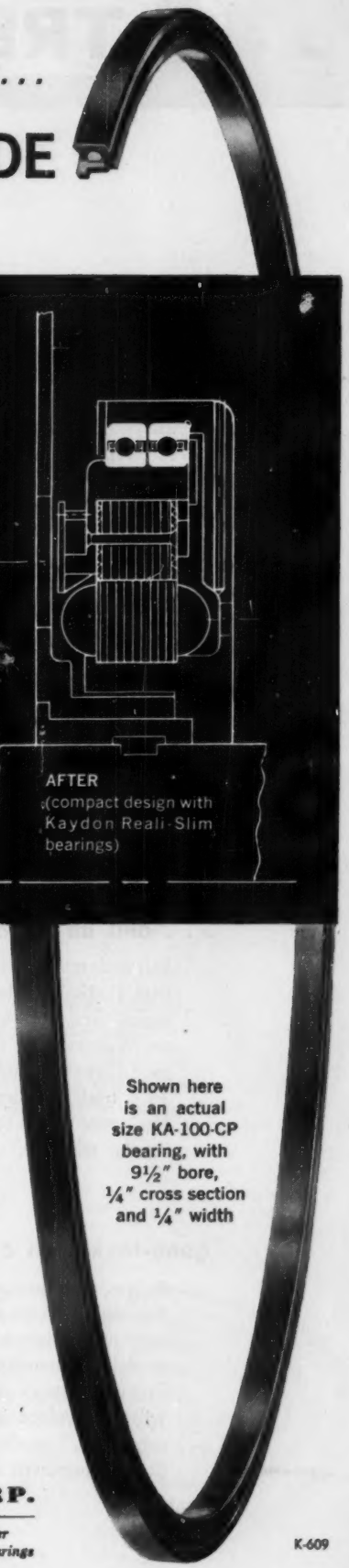
Kaydon thin-section Reali-Slim bearings provide valuable component space inside the bearing bore. And use of a hollow shaft permits utilizing this space for control rods, linkages, collets, counter-rotating shafts, clutches and brakes, to name a few possibilities.

With Reali-Slim bearings, you save weight and space in both bearing and housing, reducing costs for materials, shipping, storage and handling.

And large-bore Reali-Slim bearings give closer support to the outer edge of rotating parts, instead of the center only, which gives more rigidity and accuracy for moment loads.

Stocked in 90 sizes! These Kaydon Reali-Slim Type CP bearings have Conrad deep-groove, ball-radial construction and new bronze, one-piece snap-over separator in 4" to 12" bore—¼" to 1" width and cross section. Kaydon's volume production cuts prices up to 76%, depending on size.

Contact Kaydon now. Have the Kaydon sales engineer or distributor salesman in your area discuss Reali-Slim bearing applications for *your* products. Or write for free, fact-full "CP" bearing bulletin—with prices.



Shown here is an actual size KA-100-CP bearing, with 9½" bore, ¼" cross section and ¼" width

THE KAYDON ENGINEERING CORP.
MUSKEGON • MICHIGAN

All types of ball and roller bearings — 4" inside diameter to 178" outside diameter . . . Taper Roller Roller Thrust • Roller Radial • Needle Roller • Ball Radial • Ball Thrust • Four-Point Contact Bearings

K-609

Circle 413 on Page 19

NEWS TRENDS

safer seams in space

Because space-age super alloys are almost impossible to weld, they're now being joined by riveting or other mechanical means. In a search for reliable welding techniques, Republic Aviation Corp. (under WADD contract) is studying the cracking that occurs in iron and nickel-based high-strength alloys. Earlier this year, the company announced a broad-scale investigation of electron-beam welding, a technique that uses a concentrated beam of fast-moving electrons in a vacuum chamber to join refractory metals such as molybdenum and tungsten.

back to school for the brass

To create a core of able scientific critics among leading engineering executives, UCLA has designed a new six-week course. Taught by Dr. Edward Teller, Dr. Willard Libby, and other well-known "names," the executive-students will receive training in scientific and industrial decision making. "The situation is serious," says J. M. English, co-ordinator of the program. The executive-engineer's technical knowledge tends to be outdated. While years of experience help make up for his education decline, he needs classroom work to make skillful technical and managerial decisions.

. . . and an infrared refresher

Infrared temperature measurements are becoming so important and complex that Radiation Electronics Corp., Chicago, recently set up a school to teach technicians how to use modern instruments. Lectures and laboratory work cover everything from operating principles to how to correct for emissivity of different sources. Thirty students represented widely different industries in a trial two-day course. According to REC spokesmen, industry demand for "more of the same" is so great that the sessions are now being placed on a regular schedule.

gang-tackle on computer problems

A specialist group (numbering more than 1000) is being set up by International Business Machines Corp. for blue-sky research. The group will have only one assignment: "Lead the way into the next computer era." Mathematicians, machine experts, and industry specialists will work together, finding answers to today's unsolved problems. "In the '60s, the computer will be involved in scientific management of entire businesses and industrial complexes," predicts Gilbert E. Jones, president, IBM Data Processing Div. Better equipment and new ways to use it must be developed.

new light on electronics

A laboratory being built by Electrada Corp. will help carry electronic technology into its next major phase of development. Devoted to applications of light in electronics and chemistry, the facility is designed for new studies of the nature of light. "Because of the very small amounts of matter involved in molecular electronics," says Henry C. Jones, president of Electrada, "light plays an important part as a source of energy, an information-transfer medium, and a yardstick for extremely accurate measurements." In addition, Mr. Jones continues, "there seems to be a wide range of practical applications for devices utilizing the interaction of light and electronics."

SMU studies information centers for NSF

In an effort to find out which research men need what kind of information, Southern Methodist University will interview a fair sample of the Southwest's scientists, engineers, and technicians. Aim of the study, which is backed by a National Science Foundation Grant, is to determine whether SMU's Science Information Center can be made into a regional scientific and technical information "clearing house" serving the needs of Southwestern industrial and educational activities. SMU plans to have a report ready for the sponsor by next May.

time to sit tight?

Finding a new job is tougher now that the supply of engineers is loosening, reports the U. S. Labor Dept. In New York, employers are placing greater emphasis on graduate degrees, offering fewer openings to B.S. holders. In Chicago, firms are also stiffening their hiring standards. On the West Coast, replacement hiring is aimed at improving (but not numerically increasing) existing staffs.

off-campus Ph.D. census

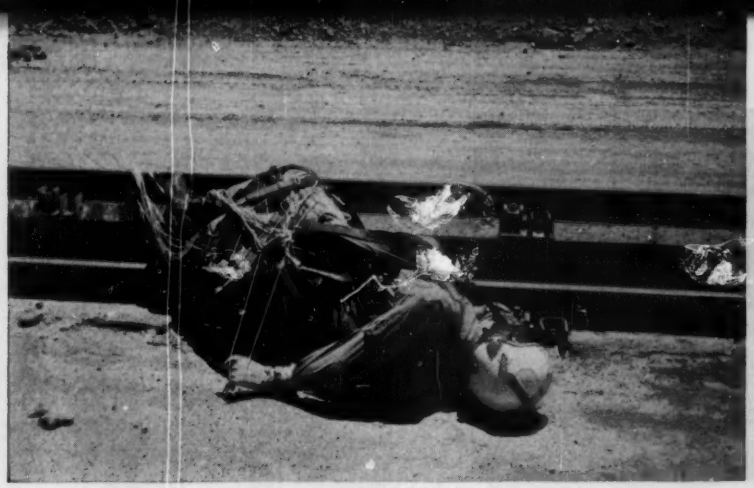
Industry employs more Ph.D.'s than all the liberal arts colleges in the country put together, says Bernard Berelson, director of Columbia's Bureau of Applied Research. The single organization with the most Ph.D. staff members isn't Harvard, Yale, or Michigan. It's Du Pont. Furthermore, General Electric has twice as many as Princeton; Shell more than MIT; Union Carbide, along with Kodak and IBM, is a standoff with Cal Tech. However, according to Berelson, the number of university research positions (now about 10 per cent of the resident staff) is growing fast, and the trend will continue where salaries are high and teaching loads are low.

H. L. DAULTON
President
Sierra Engineering Co.
Sierra Madre, Calif.

SOMETIME within the next few weeks, a manlike creature with a first-class ticket clutched in his foam-rubber hand, will board a London-bound airliner at New York's International Airport and settle in a seat for the trans-Atlantic hop. Some hours later, aided by his professor-companion, he will debark to be greeted by a prominent group of the island's scientists.

The transocean passenger is the first member of a new maritime branch in a large family of famous test dummies. His name, "Seaworthy Sierra Sam." His job—to float (or sink) just like the human being he has been contrived to represent.

Conceived 12 years ago by Sierra Engineering Co., Sierra Madre, Calif., the original Sam now has thousands of descendants, each one anthropometrically exact (hinge joints, weight distribution, center of gravity, and locations of anatomy); each is anthropomorphically ac-



Supersonic pratfalls are a common hazard in the life of Sierra Sam. He provides a realistic appraisal of human reaction and tolerance to environmental extremes.

Photos, courtesy Coleman Engineering Co.

Scientific Whipping Boy

Working closely with some of the nation's top engineering talent, a well-known dummy has played the major role in an untold number of critical military projects.

curate (external features, body contours and shape).

Sams have tested innumerable supersonic aircraft ejection seats, whirled in high-speed centrifuges, and crashed in hundreds of automobiles. Their job in all of these situations: To test human reaction to high-magnitude forces . . . without risking human life.

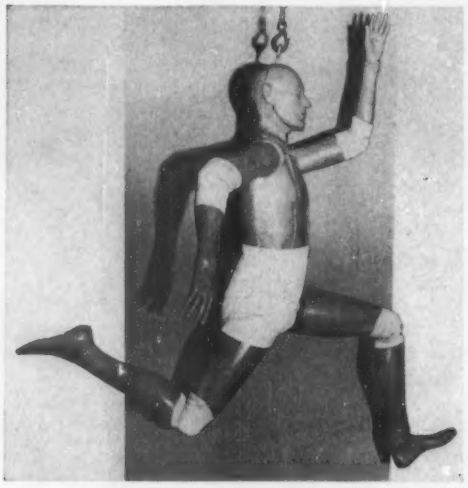
To participate meaningfully in these scientific adventures, the dummies must weigh the same as a man and have a man's body resiliency, weight distribution, and range of motion. Their flesh, bones, and body structure must respond to the test environment the same as a human's would.

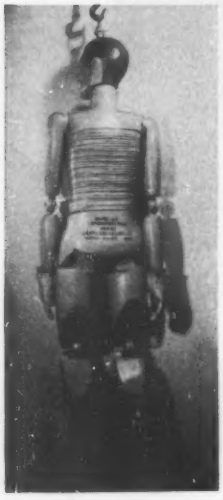
Sam's flesh is foam rubber, covered with a neoprene skin. He has a flesh-covered cast-aluminum skull. A spine of stranded steel cable with cast-steel vertebrae forms the bulwark of his strength. His arms and legs are resilient and rotational, yet snap or splinter under the stress of intolerable strain. His pre-

hensile hands, equipped with soft metal-cored fingers to permit shaping, grasp control mechanisms, handles, valves, other related parts in the equipment under test and clutch them to the death or release them at pre-arranged tensions.

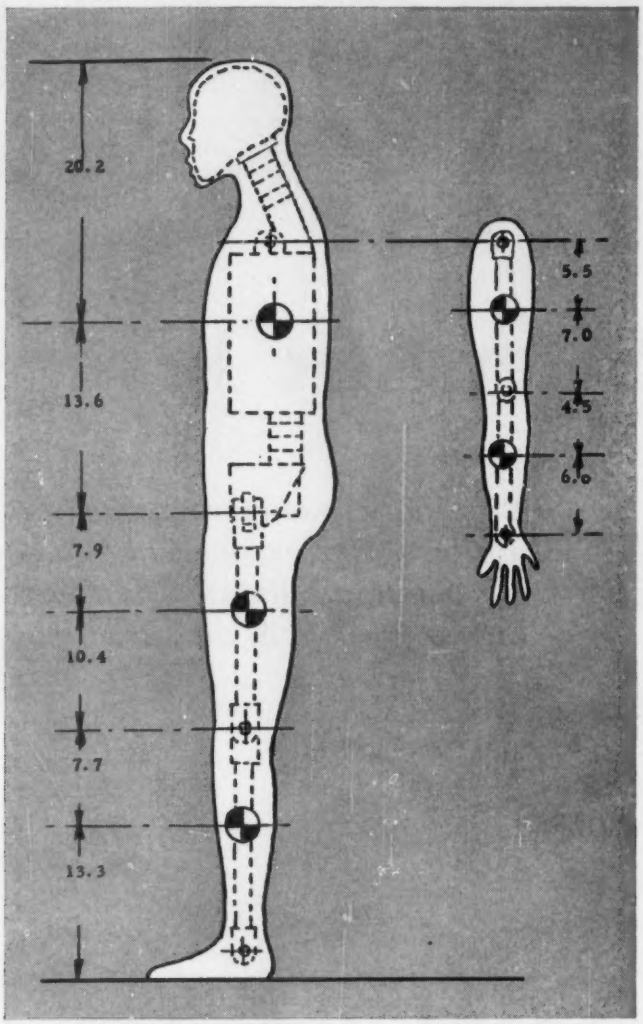
When properly equipped, Sam can perform another of man's vital abilities—communications. He "talks" with the aid of strain gages, accelerometers, transducers, rate gyros, and similar sophisticated instrumentation installed in his skull or chest cavity.

Like the human being he represents, Sam has improved through evolution. Originally a rugged, rather crude replica of man, he has developed into a refined specimen that can be made to feel heat and cold, sense shock in a way that is equivalent to pain, even bleed and breathe. And, as good men go, Sam isn't too expensive: Depending on his capabilities, he





Design of Sam's joints has been given special consideration. Axes of motion at hips, shoulders, and ankles pass through points closely resembling the effective hinge points of the human anatomy. Friction discs and adjustable tension screws simulate normal resistance to motion. Friction adjustments are made with color-coded allen wrenches from outside the dummy.



How Sam stacks up: Center of gravity, above, and weight, below, conform to that of the human anatomy.

Body Part	Weight (lb) Flesh	Skeleton	Removable Ballast	Allowed for Instruments	Deviation from Normal
Head & Neck	1.0	10.9	3.0	0.5	−0.5
Torso	11.5	66.3	12.0	16.0	+1.4
Upper Arms	3.0	6.0	..	..	−1.4
Lower Arms	2.0	3.0	..	..	−1.0
Hands	0.5	1.5	..	..	−0.5
Thighs	13.0	24.6	..	..	−1.3
Shanks	4.0	15.6	..	..	+1.5
Feet	2.0	4.0	..	..	+0.4
Girdle & Tapes	0.7	..	..	..	+0.7
Totals	37.7	130.9	15.0	16.5	−0.7

can be owned outright for between $500 and $5000.

Sam's Family Tree

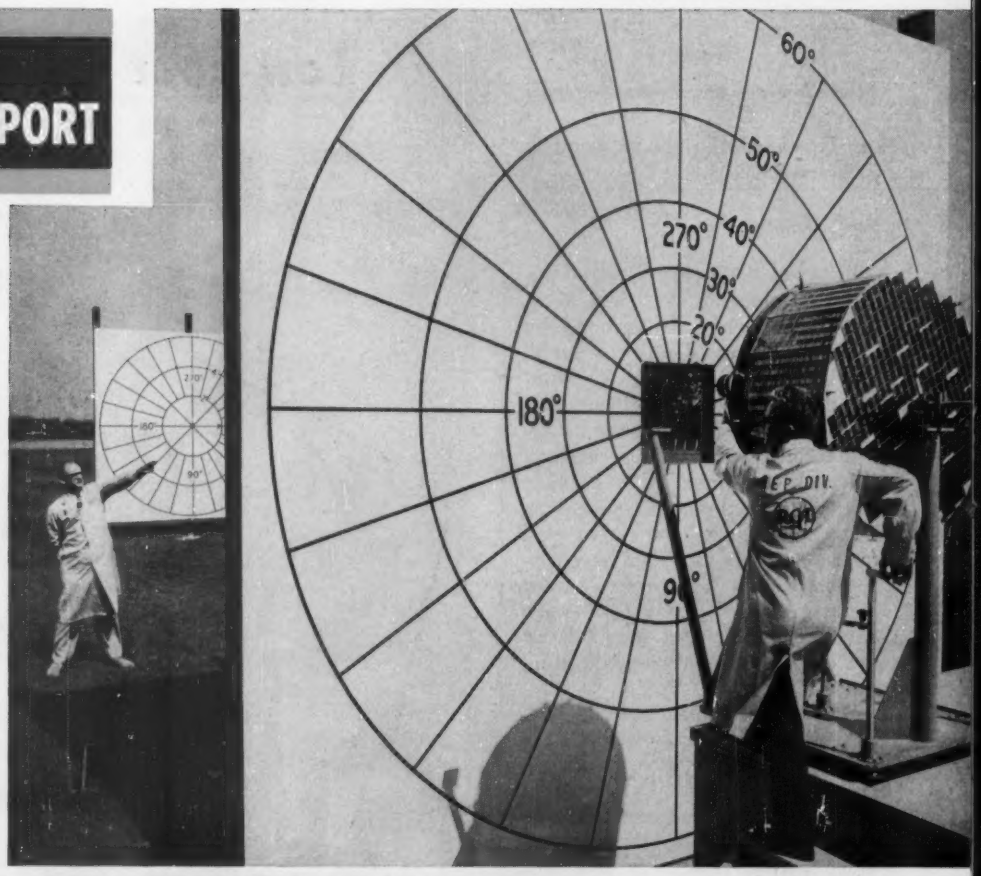
Prior to 1949 (Sam's birthday), Sierra Engineering Co. had accumulated extensive background in the development of artificial limbs. Working with the Veteran's Administration, the Army Prosthetics Research Laboratories, and similar organizations, Sierra's engineering staff was well acquainted with the basic mechanics of human engineering. Data compiled by the Sierra staff for design of the first Sam have subsequently been incorporated in Air Force Technical Report 6365—now one of the recognized standards for the design of anthropometric dummies.

Today, Sierra not only manufactures dummies, but serves as a receiving hospital for its injured progeny. Missing heads, broken backs, and burned flesh are restored or replaced by specialists, giving the average Sam an expectancy of at least nine lives.

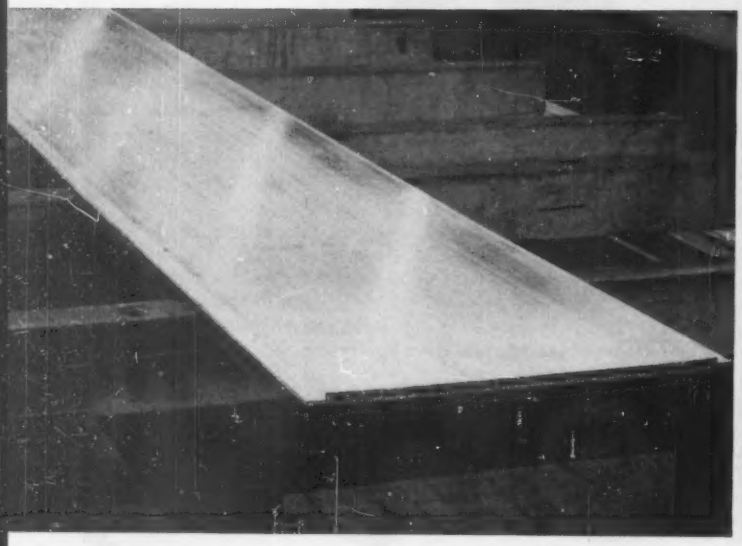
As president of Sierra Engineering Co., H. L. Daulton is probably one of the world's foremost authorities on "human engineering."

ENGINEERING NEWS

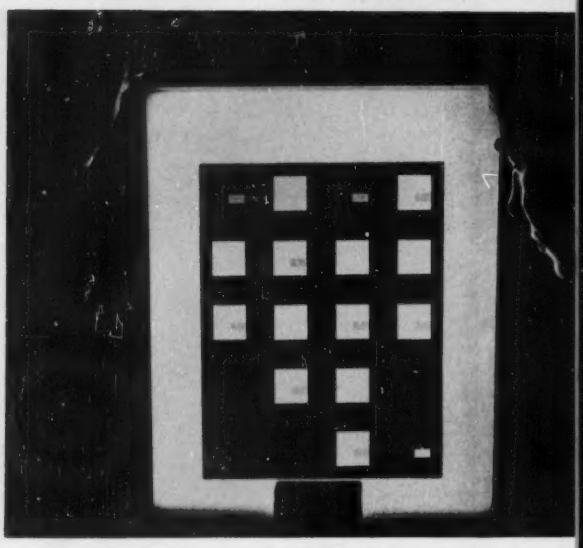
PICTURE REPORT



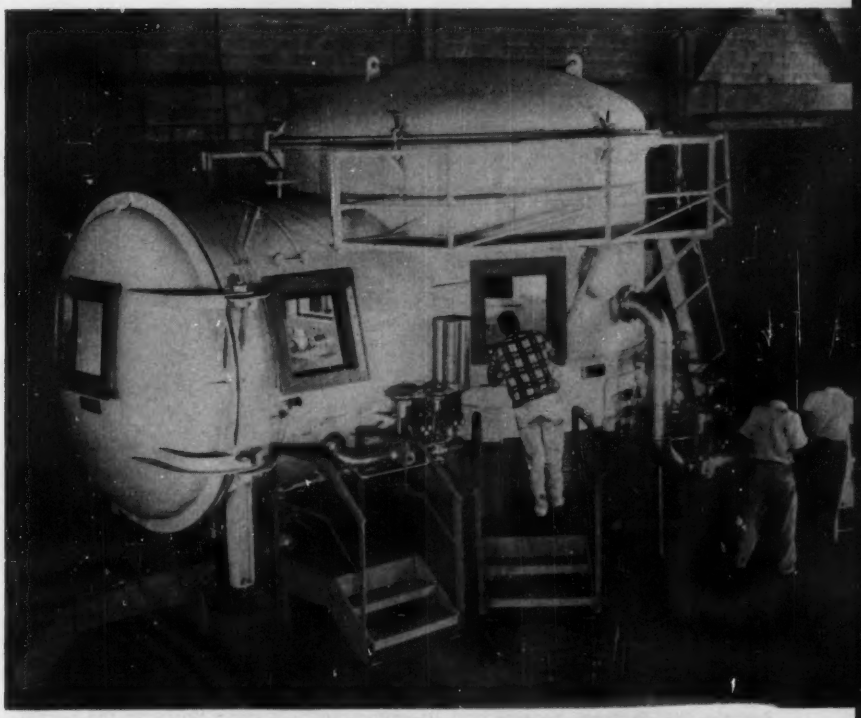
Targets for Tiros II were used to calibrate focus and field of view of the satellite's television cameras. Shown at the Space Center of Radio Corp. of America's Astro-Electronic Div., where the Tiros system was developed for NASA, the satellite is positioned for calibration of the wide-angle camera. Max Mesner, left, is in charge of TV camera design for Tiros.



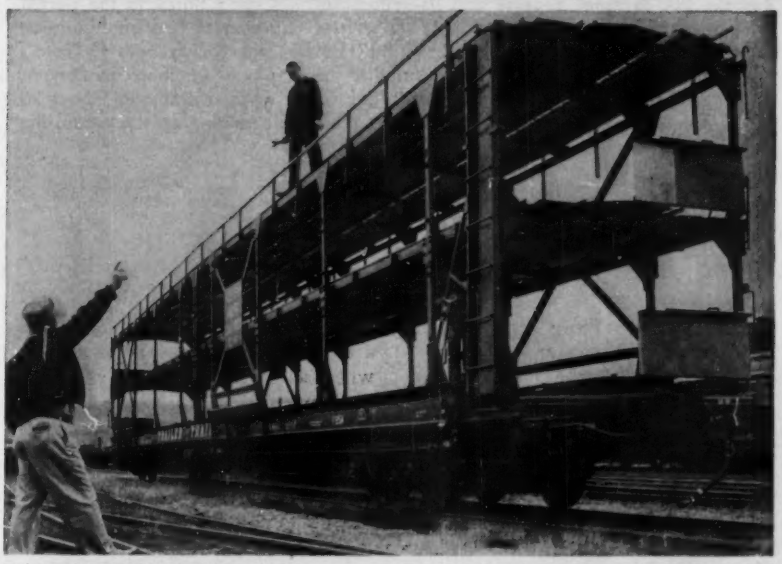
Parallel passageways ½ in. wide and 3/16 in. high run the length of 65-ft precision extrusions made by Aluminum Co. of America. The 6063 aluminum alloy panels are for fabrication into electronic-equipment cabinets for aircraft. Cool air flowing through the channels will keep the equipment at optimum operating temperatures.



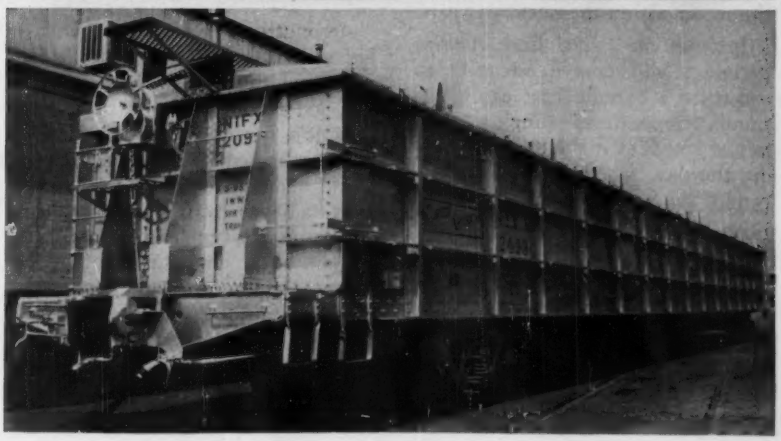
One-fourth of a memory which stores 2,250,000 bits of information, this photographic plate is used in an experimental Electronic Central Office of Bell Telephone Co. in Morris, Ill. A bit of information is recorded on the plate in the form of a magnetic dot, or the absence of a dot, in any particular location.



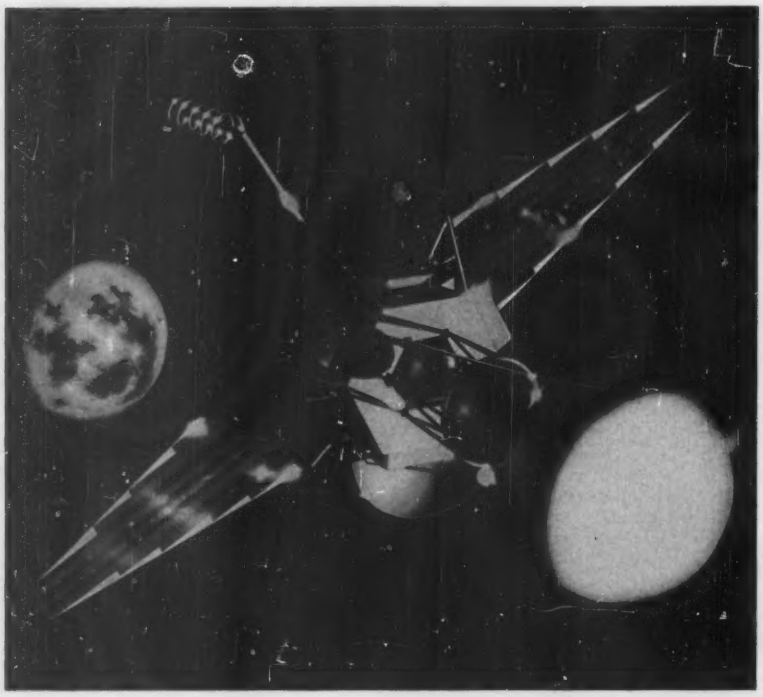
Upper space comes down to earth at Cape Canaveral with the installation of the "Mercury Pod," built by Tenney Engineering Co. to give astronauts a preview of conditions at altitudes up to 45 miles. The larger portion of the simulator holds a Mercury space capsule; the astronaut inside it can be observed from the small ante-room of the chamber, left.



Cars, cars, and more cars can be carried on ACF Industries' auto rack atop an 85-ft flatcar. A three-deck rack accommodates 12 standard or 15 compact autos; a two-decker holds 8 standard models or 10 smaller ones.



Aluminum goes to work on the railroad in a big way in this 85-ft covered gondola car. Three channel sections 82 ft long and 25 in. wide are joined mechanically to form each side of the car. Total weight is 75,900 lb—16,000 lb less than a similar car made of steel.



Bulbous 300-lb lunar capsule and its retrorocket will cling firmly to the parent Ranger spacecraft on the long trip to the moon, according to final-configuration sketches released by Ford Motor Co. The capsule, now being built by Ford's Aeronutronic Div. for NASA, will be carried to the vicinity of the moon by Ranger, will then separate from the spacecraft (triggered by a radio altimeter) about 20 or 25 miles out. For a month or more after its crash landing on the moon, the craft will telemeter vital scientific data back to Earth.

Instrument Package, Spacecraft Being Built for Trip to the Moon

Configuration Firms Up For Hard-Landing Capsule

NEWPORT BEACH, CALIF. — The bitter cold of a lunar night is being simulated by scientists at Ford Motor Company's Aeronutronic Division as part of a program to land a 300-pound instrumented package on the moon within the next two years.

Information gained from the experiment will enable scientists to construct a capsule that can withstand temperatures ranging from minus 250 F at night to 250 F during the day.

The first lunar capsule will be carried by the Ranger spacecraft which NASA's Jet Propulsion Laboratory is developing. It will be launched by an Atlas-Agena B.

The lunar capsule will contain a seismometer to detect moon quakes, temperature-recording devices, and other instruments. It will radio information back to earth for at least a month. The composite spacecraft will also transmit close-up photos of the lunar surface, up to the moment the capsule is separated from Ranger. Just before impacting, the craft will measure the moon's radioactivity at close range.

Duplicate 17-day night

Aeronutronic's vacuum test chamber was used to simulate the lunar night environment which lasts for a period equal to 17 earth days. The capsule's heat loss from radiation was measured in "hemissivites." (One hemissivite is the amount of heat radiated by a perfectly black surface at a given temperature.) As a result of these measurements, electronic equipment in the capsule is designed to operate at 75 F. Solar-powered batteries are expected to generate enough heat within the capsule to offset heat loss due to radiation.

Mars Orbit in '64 Seen for Electrically Propelled Capsule

NEW YORK—May 4, 1964, may be the date when Americans send a space capsule hurtling to Mars, according to a timetable presented at the Winter Annual Meeting of ASME.

Harold Brown, member of General Electric's Flight Propulsion Laboratory, Evendale, Ohio, suggested the May 4 date because Earth and Mars will then be in the best position to permit an electrically-propelled capsule to reach orbit around the planet. The capsule, under continuous power, would arrive in the vicinity of Mars about November 3, stabilize in orbit around that planet on January 4, 1965, according to Brown.

Electric power ups payload

Low thrust electric propulsion, in contrast to the more conventional chemical or nuclear systems, would be used, Brown continued, because the capsule could carry a much larger payload. A chemical propellant would send a capsule into orbit around Mars 215 days after it left Earth, but with a payload of only 10 per cent of vehicle weight. An electrically propelled capsule would arrive 245 days after being launched, but would carry a payload of 45 per cent. Missions would originate from a 300-mile near-circular orbit of Earth, terminate in low-altitude circular orbit about Mars.

An even greater payload could be carried in a "freight capsule," Mr. Brown suggested. This kind of space traveller would be under direct propulsion for only a comparatively short part of its journey, less fuel would be required, and more room would be left for carrying goods, even though the trip would be comparatively slow. For instance, if such a capsule left its orbit around Earth on August 18, 1964, it would need propulsion only during the week of December 24 to arrive for a Mars orbit sometime around May 29, 1965. The capsule could carry a 56 per cent payload.

"Low thrust electrical propulsion will be available for operation in space within the next few years" Mr. Brown said. NASA's powerful 1.5 million lb thrust Saturn booster will also be operational in time for the proposed Mars probe.

HAYNES ALLOYS

RESEARCH REPORTS

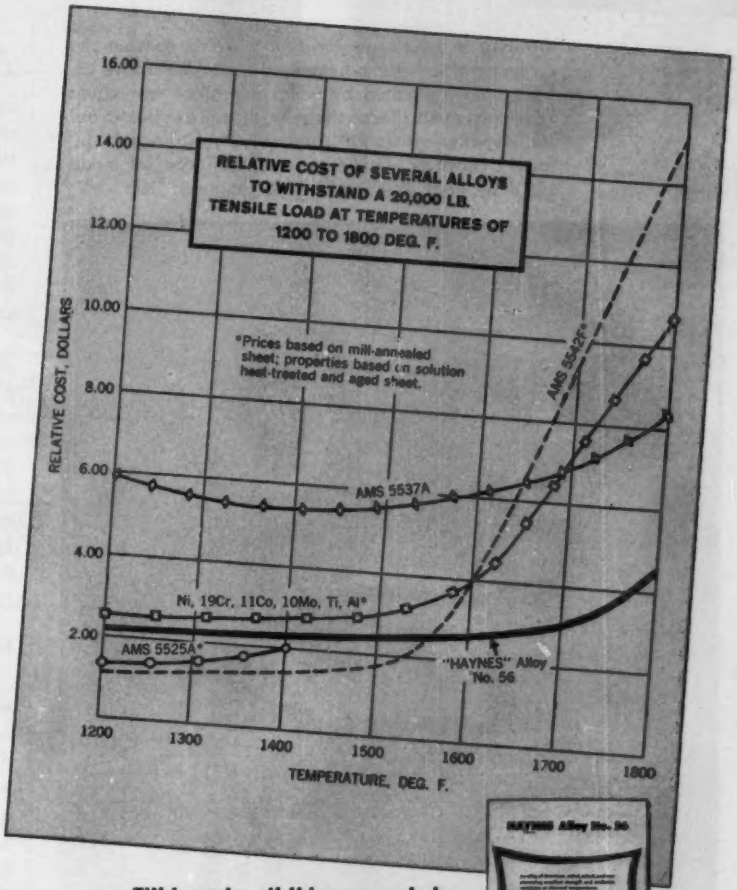
New High-Temperature Alloy Improves Cost-To-Strength Ratio

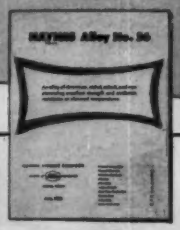
Excellent strength and oxidation resistance in the 1200 to 2000 deg. F. range are among the features of HAYNES Alloy No. 56—a new high-temperature alloy developed by Haynes Stellite Company.

A sampling of its cost advantages at a given tensile load, compared with other high-temperature alloys in the graph at the right, is well worth your study.

Alloy No. 56 can be readily hot-worked and formed. It is easy to heat treat. It comes in the form of sheet, plate, bar, wire, and coated welding electrodes, and can be furnished as sand-, investment-, and resin shell-mold castings. The coupon below will bring you a wealth of technical data.

The new iron-base alloy contains nickel, cobalt, chromium, and molybdenum. It has high strength at temperatures up to 1500 deg. F and maintains useful strength at temperatures as high as 2000 deg. F.





Fill in and mail this coupon today

Haynes Stellite Company, Dept. 61
270 Park Avenue, New York 17, N.Y.

Please mail me the free, 16-page properties-data booklet on the new HAYNES Alloy No. 56.

NAME_____

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HAYNES ALLOYS

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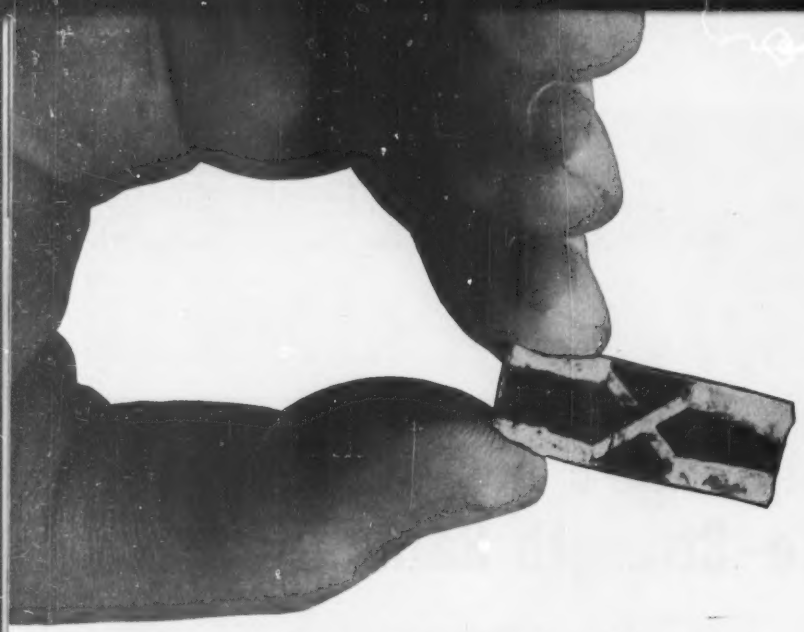


Cryogenic Tunnels

. . . first in a new family of solid-state components. They hint at still another revolution in electronics.

Offering a challenge to almost every conventional component, cryogenic-tunnels like the one above can be simply fabricated by vapor-deposition techniques. Like the tunnel diode, the new device exhibits a useful negative-resistance characteristic (strip-chart below). However, unlike the diode, it can be modulated by heat or by a varying magnetic field.

A NEW laboratory curiosity may eventually lead to electronic components that outdate everything from condensers to transistors. Electron tunneling, first observed between **p** and **n** layers of specially prepared semiconductors and harnessed in the Esaki tunnel diode, has now been teamed with cryogenics. The combination seems likely to give rise to new families of switches, diodes (with both positive and negative resistance), triodes, resistors, and capacitors.

Researchers at General Electric Co. and Arthur D. Little Inc. are experimenting with a recently discovered tunnel effect (first reported by GE's Ivar Giaever) between superconducting metals separated by a thin film of insulation. Exceptional importance is attached to the work because components expected to result will feature simpler configuration, higher reliability than present devices, easier fabrication, and lower cost to the user.

Major Advantages

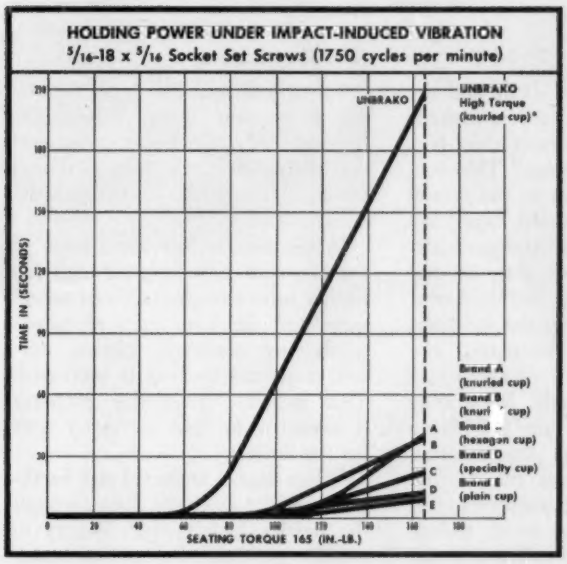
High hopes of GE and ADL physicists working on the cryogenic-tunnels are based on two important advantages the devices do not share with other circuit components:

- Superconductivity (which occurs only in a few metals when they are cooled very close to absolute zero) can be broken down by a strong magnetic field or by a temperature rise. Hence, a triode-like device (or a switch) is possible in which current is modulated by heat or magnetism.
- Fabrication is simple with modern vapor-deposition techniques. For example, at both GE and ADL, devices are built by depositing a thin layer of aluminum on a glass slide, letting the aluminum oxidize for a short time (forming a 10 to 100-atom thick insulation film), then depositing a layer of lead. Complex circuits involving hundreds of active components can be deposited in

Is it necessary to specify socket set screws by brand?

(read this—then draw your own conclusion)

If one socket set screw is *demonstrably* better than all others, we know that you will want it on your designs.



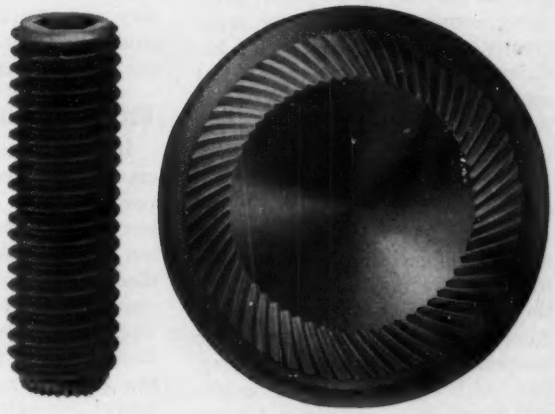
Tests conducted at SPS Laboratories for Advanced Research show UNBRAKO High Torque* with knurled cup point to be at least *five times as vibration resistant* as its closest competitor.

RECOMMENDED SOCKET SET SCREW TIGHTENING TORQUES (in.-lb.)

Screw Size	Unbrako	Set Screw B	Set Screw C	Minimum Differential %
#4	5	3.9	3.5	28
#5	9	7.8	7.4	15
#6	9	7.8	7.4	15
#8	20	14.7	14.5	36
#10	33	26.5	25	25
¼	87	62	60	40
5/16	165	122	125	32
⅜	290	198	225	29
7/16	430	309	350	23
½	620	460	500	24
5/8	1225	1106	1060	11
¾	2125	1540	1800	18
⅞	5000	3660	4600	9
1	7000	5025	6500	8

Note well that this test was held with all screws at the same torque. Now, when we realize that with UNBRAKO the tightening torques are as much as 40% higher than those for ordinary set screws, the gap between High Torque and competitive brands becomes even greater.

Nor is there anything mysterious about the superiority of UNBRAKO. Certainly one of the main reasons—and one



that the naked eye can perceive—is the exclusive knurled cup point, which enables this screw to grip with such tenacity that it is literally self-locking.

Other signally important features that help to explain the unparalleled holding power of UNBRAKO High Torque:

- Fully formed threads with metal compressed into a closely knit grain structure and no straight lines along which shear can occur
- Precision heat treated steel to eliminate brittleness or decarburization
- Deeper sockets for maximum key engagement and wrenching power
- Radius sockets to eliminate sharp corners where cracks start during tightening

Why leave reliability to luck? Wouldn't it be wise to insist on UNBRAKO High Torque socket set screws.

* * *

UNBRAKO High Torque socket set screws are available in sizes #0 through 1 in., in alloy and stainless steels, and with Nylok†. Ask your authorized industrial distributor for complete information or write to STANDARD PRESSED STEEL CO. for booklet "More about UNBRAKO High Torque Set Screws." INDUSTRIAL FASTENER Division, SPS, JENKINTOWN 18, PENNSYLVANIA.

*Standard ... they sell at regular price
†T.M. Reg. U.S. Pat. Off., The Nylok Corporation

SPS

where reliability replaces probability

Circle 416 on Page 19

one operation. Compared to present methods of fabricating and assembling electronic circuits, costs appear to be practically negligible.

Other advantages of the cryotunnels include a large reduction in size of components, low power requirements, and a potential packaging density that is many times greater than now possible. In addition, only small amounts of heat are generated and the devices should operate at extremely high frequencies.

Temperatures Pose No Problem

A great deal of applied research and development will be required to evolve practical devices based on the cryogenic-tunneling concept. Also, the requirement of cryogenic temperatures may be a handicap, but neither GE nor ADL expect this drawback to be serious in many applications.

Small liquid-helium refrigerators are now available, and low power-dissipation characteristics may make cooling less of a problem than with large, compact arrays of present components. According to Dr. Guy Suits, vice president and director of GE's research, "technology for achieving cryogenic temperatures is advancing quite rapidly . . . Progress may be compared to the progress made in high-vacuum technology, which easily overcame obstacles and fully satisfied the demand for vacuum devices."

The cryotunnel receiving most attention so far is the aluminum-aluminum oxide-lead sandwich, but other materials will also work. Some combinations of indium, tin, lead, and aluminum have been successful, and while aluminum oxide is the most tested insulating layer, data show tantalum oxide, niobium oxide, and nickel oxide also permit the tunneling effect.

ABCs of Tunneling

In both the tunnel diode and the cryotunnel, a special current is made possible by an extremely thin barrier between the "poles." This barrier, the p-n junction in the tunnel diode and the oxidized layer between metals in the cryogenic device, passes electrons that do not have enough energy to "flow over the top." In a sense, the electrons tunnel through the insulating material.

In the tunnel diode, low-energy tunneling electrons are picked up in valence shells by the electron-starved "holes" across the barrier. However, as bias is increased, the tunnelers acquire too much energy to be captured in valence shells, but they still don't have enough energy to work their way into conduction bands. Hence, current falls off, giving the device a negative-resistance characteristic.

In the cryotunnel, tunneling electrons are the special ones that allow some metals to be superconductors at low temperatures. They are not important in "regular" electronics. While scientists are not yet sure of all the properties of superconducting electrons, some speculate that there are two types with widely different energy levels. Superconducting atoms can pass along each type, but they cannot work with electrons having intermediate energies.

How They Behave

In an unbiased cryogenic tunneler, no current flows. When bias is slight, the lower-energy superconducting electrons start to tunnel through. Current builds up with the bias.

When bias is increased, some of the electrons tunneling through the barrier have energies between values permitted the two types of superconducting electrons. Hence, current decreases as bias is increased. This negative resistance property is expected to lead to many uses for the device.

When bias is increased still further, tunneling electrons come through the barrier with enough energy to qualify as higher-energy superconducting electrons. Current again builds up with bias.

Since neither side of the cryogenic tunnel is inherently negative or positive, reversing the bias reverses the direction of current flow, just as in a resistor.

Meetings and Shows

Jan. 9-13—

Society of Automotive Engineers Inc. International Congress and Exposition of Automotive Engineering to be held at Cobo Hall, Detroit. Additional information is available from the society, 485 Lexington Ave., New York 17, N. Y.

Jan. 17-19—

Instrument Society of America. Winter Instrument - Automation Conference and Exhibit to be held at the Sheraton-Jefferson Hotel and Kiel Auditorium, St. Louis. Further information can be obtained from ISA headquarters, 313 Sixth Ave., Pittsburgh 22, Pa.

Jan. 23-25—

Institute of the Aerospace Sciences. Annual Meeting to be held at the Hotel Astor, New York. Honors Night Dinner is Jan. 24. Further information is available from IAS headquarters, 2 E. 64th St., New York 21, N. Y.

Jan. 29-Feb. 3—

American Institute of Electrical Engineers. Winter General Meeting to be held at the Hotel Statler, New York. Further information is available from AIEE headquarters, 33 W. 39th St., New York 18, N. Y.

Feb. 1-3—

Second Winter Military Elec-

". . . this T-square you misplaced. Can you describe it?"

Circle 417 on Page 19→

WHY THIS IS A BETTER *LATCHING* RELAY

Better? Yes, in several ways. Bifurcated Contacts, for example, give improved reliability, especially in dry circuits. Contacts will not open during vibrations of 30Gs, 55 to 2500 cps. A special method of sealing cover to base eliminates flux contamination of the contacts. And there are more. Here is Potter & Brumfield's newest member of a distinguished family of micro-miniature relays: the FL Series.

Expressly designed for printed circuit applications, this DPDT, 3 amperes (@ 30V DC) latching relay lies parallel to the mounting surface. Its height, when mounted, is only .485", thus circuit boards may be stacked closer. Mounting can usually be accomplished without studs or brackets, simplifying installation.

The FL will remain firmly latched in either armature position without applied power, a significant advantage where power is limited and long relay "on" times are required. This relay may be operated by:

1. Pulsing each coil alternately (observing coil polarity), or
2. Connecting the coils in series and operating from a reversing (polarized) source.

Write for complete information or call your nearest P&B representative.

FL SERIES SPECIFICATIONS

Shock: 100 Gs for 11 milliseconds. No contact openings.

Vibration: .195", no contact openings. 10 to 55 cps. 30 Gs from 55 to 2500 cps.

Pull-In: 150 milliwatts maximum (standard) at 25° C. 80 milliwatts maximum (special) at 25° C.

Operate Time: 3 milliseconds maximum at nominal voltage at 25° C.

Transfer Time: 0.5 millisecond maximum at nominal voltage at 25° C.

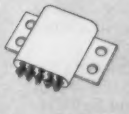
Temperature Range: −65° C to +125° C.

Terminals: Plug-in pins.

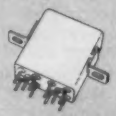
Dimensions: L. 1.100" Max.—W. .925" Max H. .485" Max. Hermetically sealed only.

SC 11 D

SCG 11 DC



SL 11 DB
(Latching)



SLG 11 DA
(Latching)

Other P&B micro-miniature relays include conventional and latching models in crystal cases with a wide range of terminals and mountings. All are made in a near-surgically clean production area under the exacting requirements of our Intensified Control and Reliability program.

P&B STANDARD RELAYS ARE AVAILABLE AT YOUR LOCAL ELECTRONIC PARTS DISTRIBUTOR

YOUR BEST SINGLE SOURCE FOR ALL MICRO-MINIATURE RELAYS

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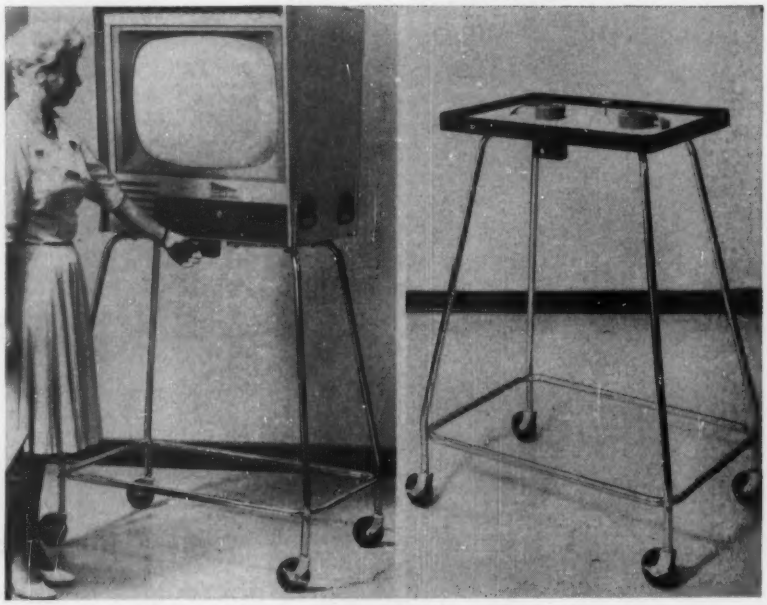

TV Goes to School on Stand That Is Antenna

Tubular legs of a new television stand can be connected to the set in different combinations to act as directional, high-gain indoor antennas. Selection of antenna combinations is made by turning a knob on the front of the stand. Elimination of a separate antenna is one of the safety features of the stand, designed especially for classroom use by Transvision Electronics Inc., New Rochelle, N. Y. The line includes 40 and 48 in. high stands.

tronics Convention to be held at the Biltmore Hotel, Los Angeles. Sponsors are the National Professional Group on Military Electronics and the Institute of Radio Engineers, Los Angeles section. Additional information is available from IRE, 1435 S. La Cienega Blvd., Los Angeles 35, Calif.

Feb. 7-9—

Society of the Plastics Industry Inc. Sixteenth Reinforced Plastics Div. Conference to be held at the Edgewater Beach Hotel, Chicago. Further information can be obtained from SPI headquarters, 250 Park Ave., New York 17, N. Y.

Feb. 9-11—

National Society of Professional Engineers. Winter Meeting to be held at Hotel Fort Des Moines, Des Moines, Iowa. Further information can be obtained from NSPE headquarters, 2029 K. St. N.W., Washington 6, D. C.

Feb. 13-16—

American Society of Heating, Refrigerating and Air-Conditioning Engineers. National Meeting and 15th International Heating & Air-Conditioning Exposition to be held at the International Amphitheatre, Chicago. Additional information can be obtained from exposition headquarters, 480 Lexington Ave., New York 17, N. Y.

March 5-9—

American Society of Mechanical Engineers. Gas Turbine Power Conference and Exhibit to be held at the Shoreham Hotel, Washington, D. C. Co-sponsor is the U. S. Dept. of Defense. Further information can be obtained from ASME Meetings Dept., 29 W. 39th St., New York 18, N. Y.

March 16-17—

American Society of Mechanical Engineers. Textile Engineering Conference to be held at Clemson College, Clemson, S. C. Additional information can be obtained from ASME Meetings Dept., 29 W. 39th

Circle 419 on Page 19→

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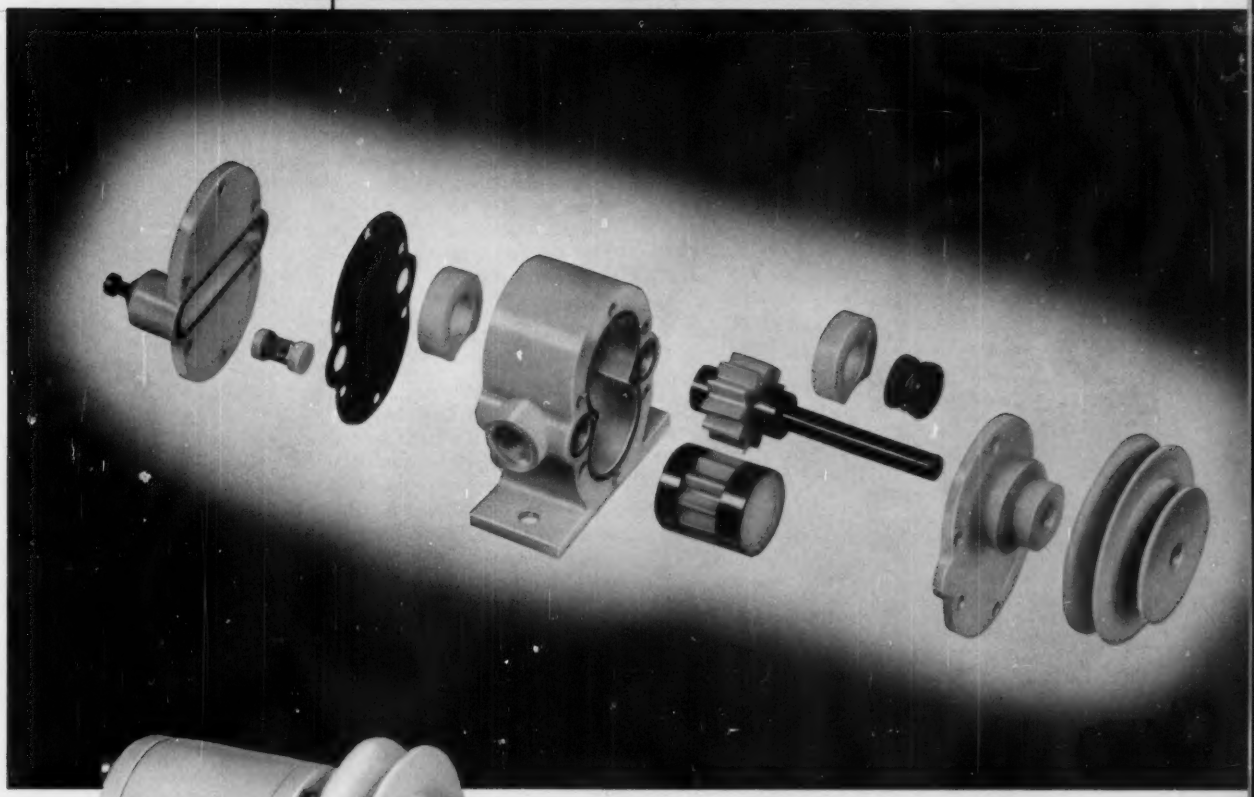
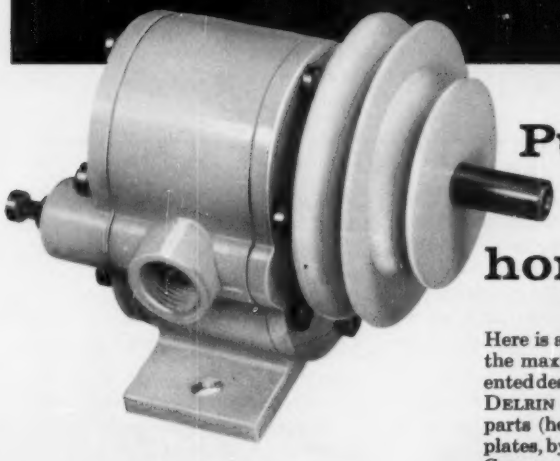
Du Pont Delrin®

one of Du Pont's versatile engineering materials





Pump parts of DELRIN® cut costs...reduce horsepower requirements

Here is a new gear pump that attains the maximum advantages of its patented design features by using Du Pont DELRIN acetal resin for all the major parts (housing, gears, bearings, cover plates, bypass valve and drive sheave). Compared with rotary pumps now made in brass and other metals, the new pump of DELRIN has better efficiency, less heat buildup, improved bearing characteristics with no lubrication, quieter operation and longer life. The manufacturer reports that the low friction of DELRIN reduces horsepower requirements as much as 50% over comparable models in brass.

In addition, economical injection molding of these parts to close tolerances—plus the elimination of expensive finishing operations—provides the greatest possible savings in pump cost. The pump parts are molded by Artag Plastics Corporation and Chicago Molded Products for Planet Products of Chicago, Illinois.

As in most applications, it is a *combination* of property advantages that makes DELRIN outstanding in performance. The different parts of the pump depend, in varying degrees, on such properties of DELRIN as: high strength, stiffness, creep resistance, corrosion resistance, non-lubricated bearing characteristics, low friction, dimensional stability, abrasion resistance and excellent fatigue life while subjected to a range of temperatures and environments.

On the following page, you'll find more examples of how these properties are being used to improve the performance and lower the production costs of a variety of pumps. The details may well stimulate your thinking about the advantages of DELRIN for *your* products.

DU PONT

REG. U.S. PAT. OFF.

BETTER THINGS FOR BETTER LIVING THROUGH CHEMISTRY

St., New York 18, N. Y.

March 20-23—

Institute of Radio Engineers. International Convention to be held at the Coliseum and the Waldorf-Astoria Hotel, New York. Additional information is available from IRE, 1 E. 79th St., New York 21, N. Y.

March 20-24—

American Society for Metals. Thirteenth Western Metal Exposition & Congress to be held at the Pan Pacific Auditorium, Los Angeles. Additional information can be obtained from ASM, Metals Park, Novelty, Ohio.

March 21-23—

American Power Conference to be held at the Sherman Hotel, Chicago. Sponsors are nine engineering societies, including American Society of Mechanical Engineers, National Association of Power Engineers, American Institute of Electrical Engineers, American Society of Civil Engineers, and American Society of Heating, Refrigeration, and Air Conditioning Engineers; Illinois Institute of Technology and 13 other universities. Additional information can be obtained from the conference director, R. A. Budenholzer, Illinois Institute of Technology, 35 W. 33rd St., Chicago 16, Ill.

Short Courses and Symposia

Jan. 9-11—

Seventh National Symposium on Reliability and Quality Control to be held at the Bellevue-Stratford Hotel, Philadelphia. Sponsors are the Institute of Radio Engineers, American Institute of Electrical Engineers, American Society for Quality Control, and Electronic Industries Association. Additional information can be obtained from James H. Goodman, Radio Corp. of America, Bldg. 1-2, Camden 2, N. J.

Jan. 11-12—

Quality Control Seminar, sponsored by the American Society of Tool and Manufacturing Engineers, to be held at the Chase Park Plaza, St. Louis. Additional information can be obtained from ASTME headquarters, 10700 Puritan Ave., Detroit 38, Mich.

Jan. 18-19—

Seminar on Machining and Forming Space-Age Metals to be held at the Statler-Hilton Hotel, Dallas. Sponsor is the American Society of Tool and Manufacturing Engineers, and further information can be obtained from the society, 10700 Puritan Ave., Detroit 38, Mich.

Jan. 23-Feb. 2—

Engineering and Management Course to be held at UCLA. Participants select four classes from a group of 22, including such subjects as reliability for modern industry, industrial psychology, engineering and research administration, and effective managerial communication. Public speaking classes are also offered. Further information can be obtained from Reno R. Cole, Co-ordinator, The Engineering and Management Course, College of Engineering, University of California, Los Angeles 24, Calif.

Feb. 14-16—

Second Annual Symposium on Nondestructive Testing of Aircraft and Missile Components (unclassified) to be held at the Gunter Hotel, San Antonio, Texas. Sponsors are the South Texas Section of the Society for Nondestructive Testing Inc. and Southwest Research Institute; further information is available from R. B. Wangler, Southwest Research Institute, P. O. Box 2296, San Antonio, Texas.

March 20-31—

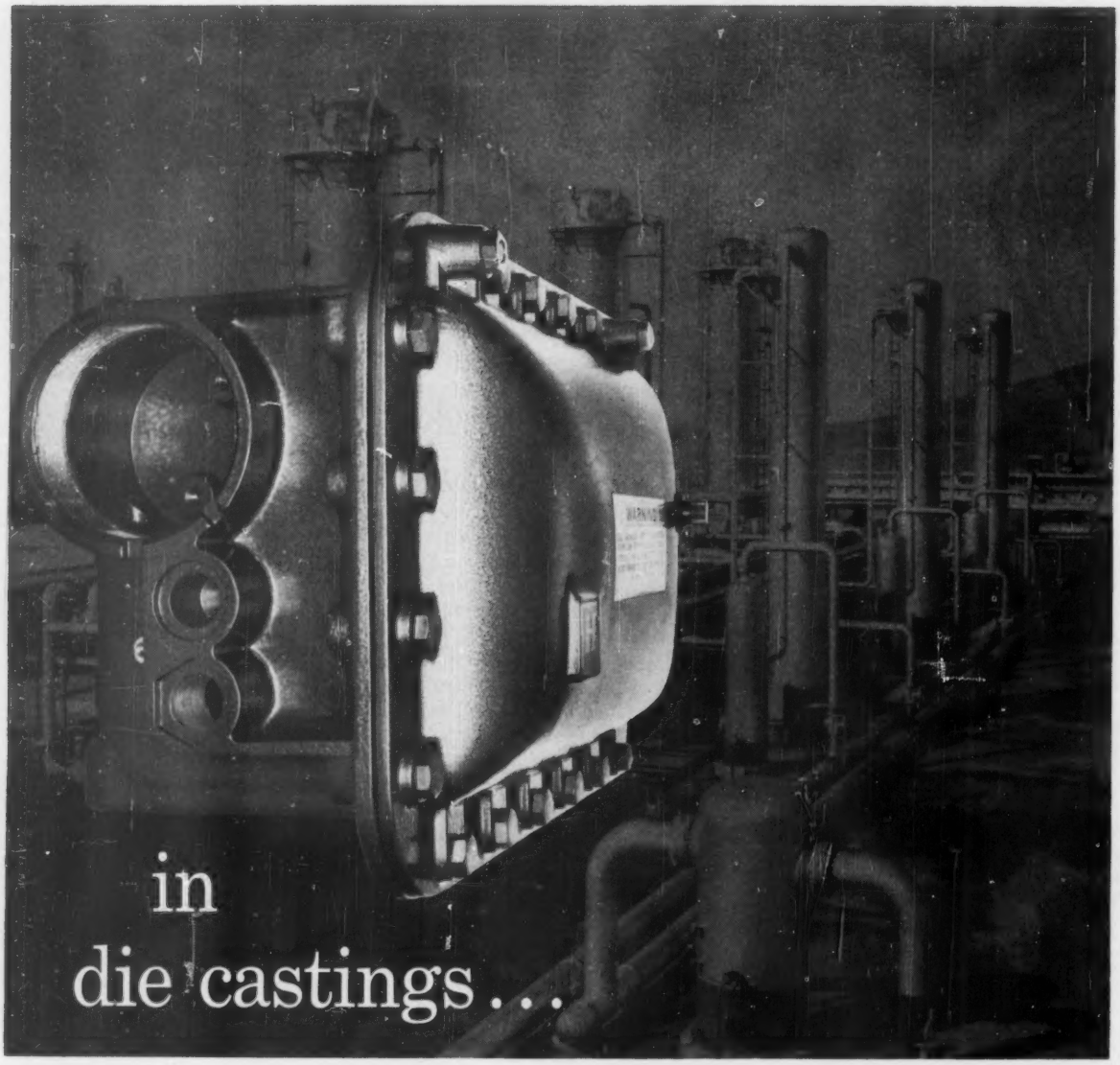
Industrial Packaging Short Course to be held at Purdue University. Additional information is available from Mark E. Ocker, Conference Co-ordinator, Div. of Adult Education, Memorial Center, Purdue University, Lafayette, Ind.

March 27-31—

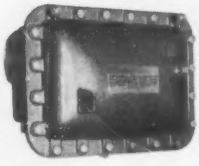
Third Symposium on Temperature—Its Measurement and Control in Science and Industry to be held at Veterans Memorial Auditorium, Columbus, Ohio. Sponsors are Instrument Society of America, American Institute of Physics, and National Bureau of Standards. Further information is available from ISA, 313 Sixth Ave., Pittsburgh 22, Pa.

←Circle 419 on Page 19

Circle 420 on Page 19



Alcoa puts the metal where you want it



High-volume output and low cost were the twin objectives. That's why Minneapolis-Honeywell decided its new Process Pressure Transmitter must be housed in an aluminum die casting.

The housing had to be explosion-proof—for it would operate in Class 1, Group D, Division 1 locations. This called for thick walls—especially so for die casting. Mating faces had to meet flush—metal to metal—without gaskets.

These were stiff conditions—demanding a new application of the die-casting process.

Honeywell turned to Alcoa—the company with the most experience in the aluminum industry.

Working closely with Honeywell, Alcoa development engineers designed a die casting that's little short of stupendous. It's made of Alcoa's new high-strength, high-elongation casting alloy 364, which has the properties of alloy 218. Yet, the new alloy is more economical because it is easier to cast.

Hydrostatic tests proved that sand-cast prototypes withstand 500 psi, more than enough to assure that castings would withstand explosive pressures up to 125 psi. Mating faces—*as cast*—meet with an integrity that eliminates any need for a gasket.

In castings as well as forgings, impacts, extrusions and screw machine parts, Alcoa puts the metal where you want it. Learn more about Alcoa's ingenious solutions to difficult design problems—write to Aluminum Company of America, 905-M Alcoa Building, Pittsburgh 19, Pa.

For exciting drama watch ALCOA PRESENTS every Tuesday evening, ABC-TV

ALCOA ALUMINUM

ALUMINUM COMPANY OF AMERICA

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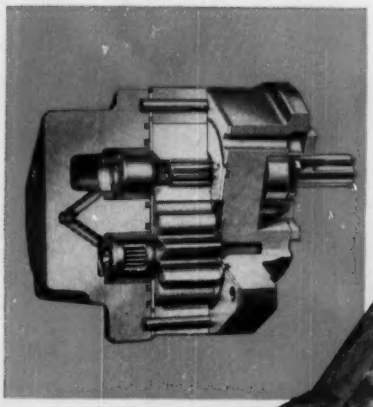
Webster hydraulics "muscle" a boardinghouse reach . . .

It stretches way out for a hearty bite, digs deep and unloads high over a truck side. Hydraulics give this versatile backhoe its sure-footed stance, swivel-hipped performance, accurate bucket and boom control. In many of these mobile rigs, a Webster JD hydraulic pump powers the action — in up to seven separate cylinders!

Not an unusual assignment — for the JD series has an uncanny ability to handle demanding jobs with speed, sureness and exceptional dependability. That's why you find them on a wide range of industrial, agricultural and construction machines . . . in pressure lubricating, oil circulating and lift systems.

Webster JD positive displacement, gear-type pumps are available in 5 sizes — from 5 to 23 gpm — with pressures to 2000 psi, speeds to 2400 rpm. Drive is direct, gear or belt. Side porting standard, end optional. Compact design fits into tight corners.

Need help in a specific hydraulic application? A specially trained Webster hydraulics engineer is ready to assist you. Write for action!



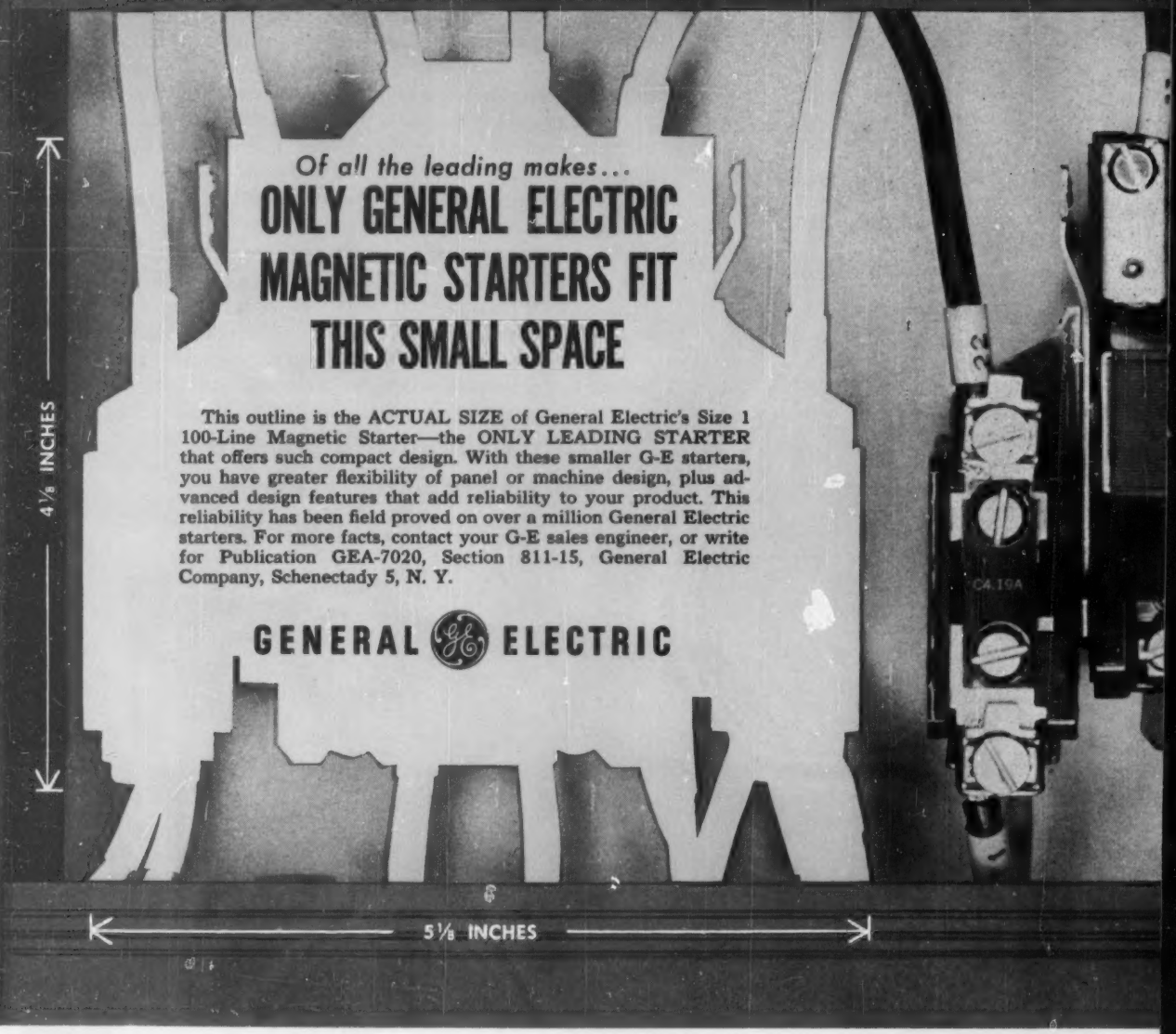
JD SERIES POSITIVE DISPLACEMENT GEAR-TYPE PUMP — Send for complete engineering characteristics performance and installation data.

OIL HYDRAULICS DIVISION

WEBSTER ELECTRIC

RACINE · WIS

Circle 422 on Page 19



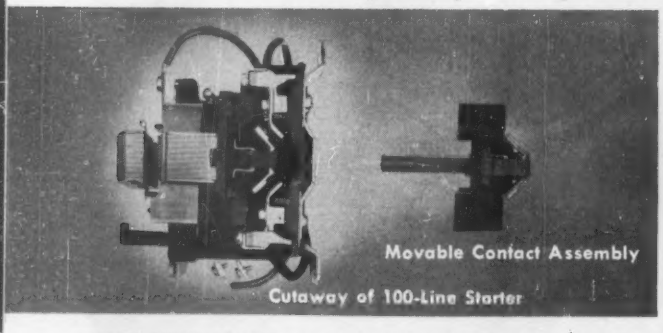
Of all the leading makes...

ONLY GENERAL ELECTRIC MAGNETIC STARTERS FIT THIS SMALL SPACE

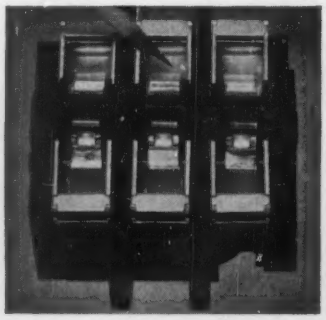
This outline is the ACTUAL SIZE of General Electric's Size 1 100-Line Magnetic Starter—the ONLY LEADING STARTER that offers such compact design. With these smaller G-E starters, you have greater flexibility of panel or machine design, plus advanced design features that add reliability to your product. This reliability has been field proved on over a million General Electric starters. For more facts, contact your G-E sales engineer, or write for Publication GEA-7020, Section 811-15, General Electric Company, Schenectady 5, N. Y.

GENERAL ELECTRIC

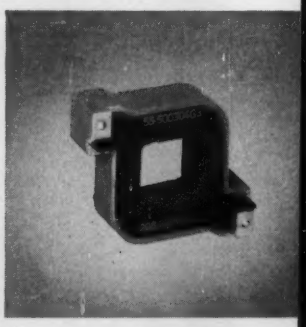
Add reliability to your product by using 100-Line starters



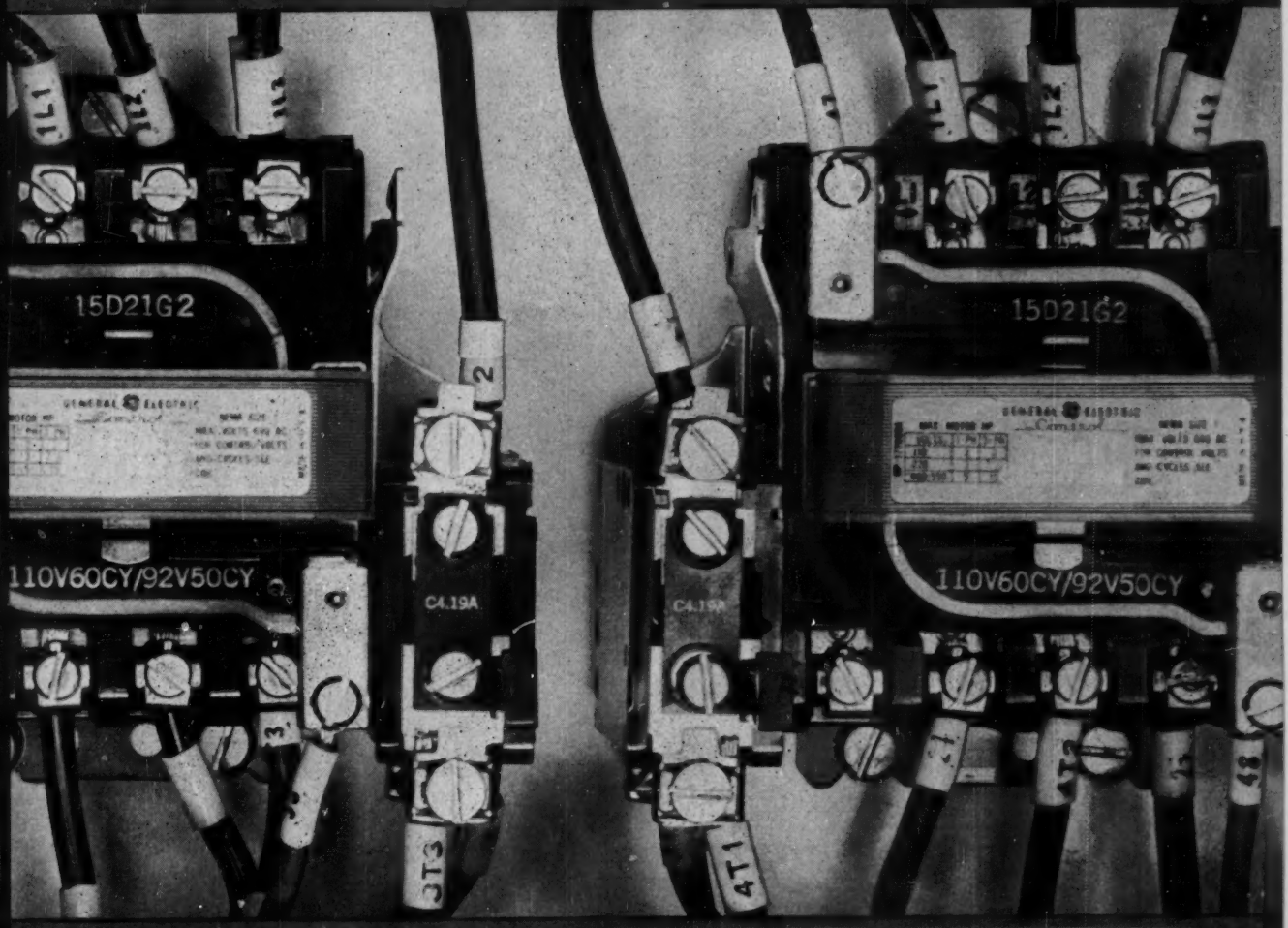
LESS BOUNCE, LONGER LIFE RESULT FROM SLANTED CONTACT DESIGN, HORIZONTAL ACTION. Bounce on closing and dust accumulation are two major causes of contact deterioration. General Electric's slanted contacts and horizontal action virtually eliminate both problems. The unique angled mating of contact surfaces provides positive "make" and "break," with less bounce, less resultant arcing. The slanted surfaces shrug off dust and other contaminates that could cause contact pitting.



MAGNETIC STEEL ARC TRAP EXHAUSTS CONDUCTIVE GASES, REDUCES CONTACT EROSION. Size 2 starters feature arc trap which exhausts ionized gases, contains and quenches arcs. Arc trap splits and cools arcs quickly, reducing contact erosion, extending contact life.

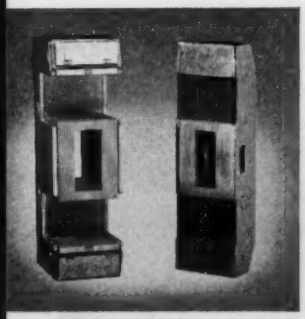


STRONGBOX MOLDED COIL PROVIDES POSITIVE PROTECTION FOR COIL WINDINGS. Glass-filled alkyd resin protects coil to prevent flexing of windings, and resists dirt, oil, water, and mechanical damage.

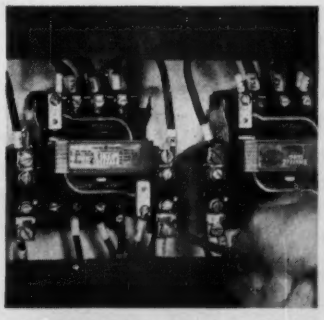


You get **MEASURABLE ADVANTAGES** with **GENERAL ELECTRIC CONTROL**

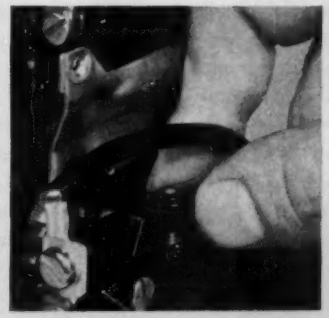
Only General Electric gives you all these proved features



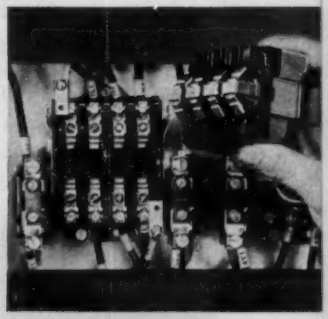
POSITIVE "MAKE," CLEAN DROP-OUT PROVIDED BY G-E MAGNET DESIGN. Any voltage sufficient to move magnet seats it firmly. Clean drop-out results from machined air-gap, short flux path.



STRAIGHT THROUGH WIRING ALLOWS QUICK, NEAT INSTALLATION. All line terminals are at top, all load terminals at bottom. This speeds installation, provides neater appearance. Pressure type terminals accept solid or stranded wire, ring or spade connectors.



BIMETALLIC OVERLOAD RELAYS ARE TRIP-FREE, ADJUSTABLE ±15%. Bimetallic relays standard on 100-Line starters, cannot be reset while overload exists. Handy knob allows ±15% adjustment of trip setting. Overloads can be reset manually or automatically.



FULL-FRONT ACCESSIBILITY ALLOWS EASIER INSPECTION, WIRING, MODIFICATION. No extra space needed—contact inspection, coil change, overload adjustment done from front.

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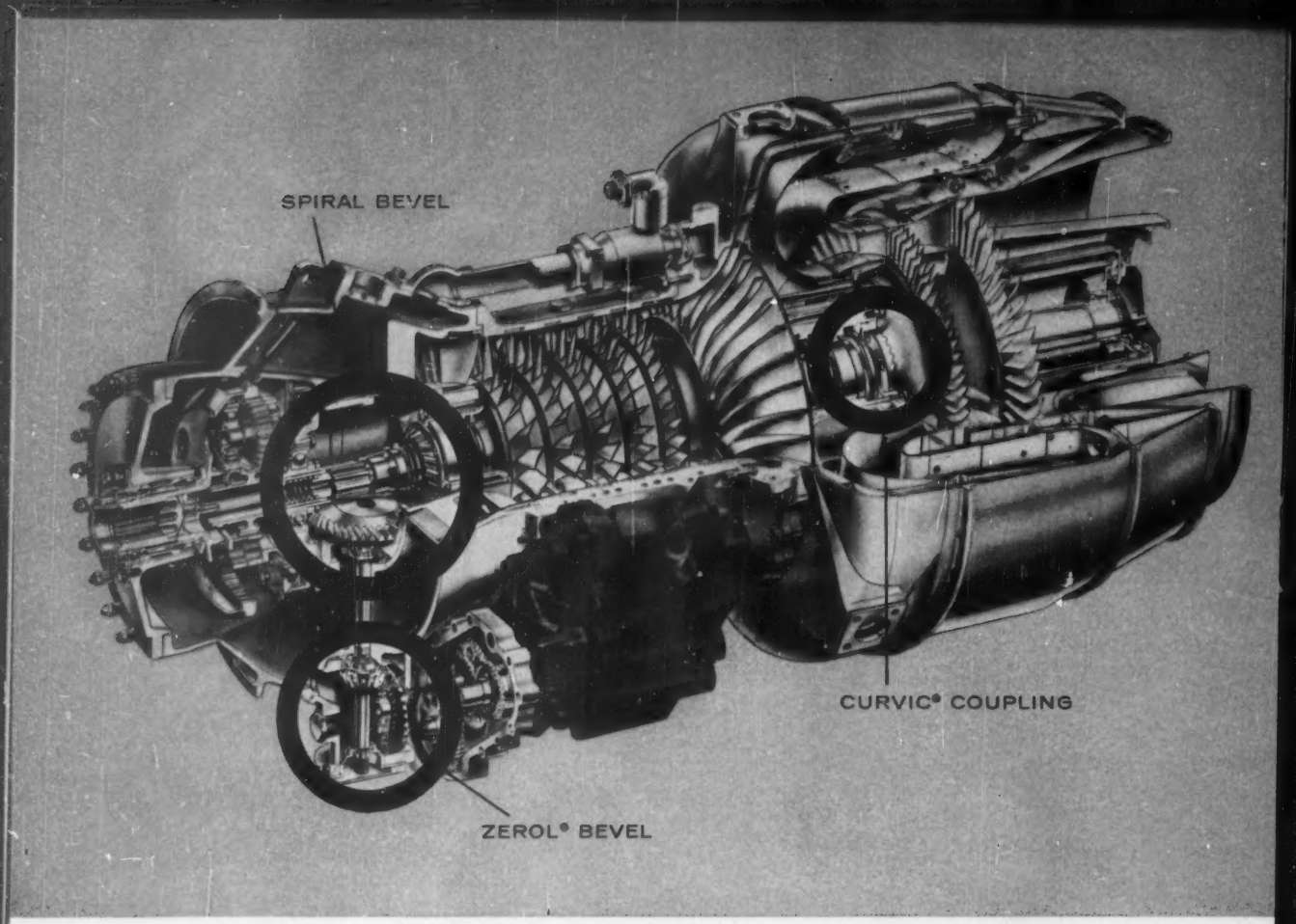


How to get *engineering assistance* on gears and couplings like these

Gleason engineers are always ready to help you work out any problems involving bevel gears and couplings.

Such assistance came to the makers of this turbine in four different areas:

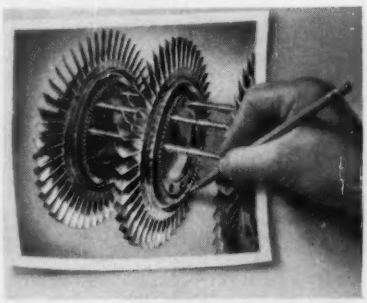
First, they naturally wanted components which met the designated theoretical requirements of the turbine. Our engineers helped determine the types and sizes of the gears and Curvic® coupling as well as such details as axial thrust and radial load.

Second, they wanted compactness. The angular drives made possible by the spiral bevel and Zerol® bevel systems helped materially to fit the drive into the limitations set by the turbine's over-all dimensions.

Third, they wanted low costs. The machines and methods developed by Gleason engineers assure the lowest possible costs for both gears and couplings whether made in small or large quantities. The Curvic coupling design inherently cuts coupling costs; see picture at right.

Fourth, the makers wanted extreme reliability. The success of the gears and couplings in this respect is witnessed by the fact that this turbine is used by six major aircraft companies and has recorded more hours of flying time than any other turbine in its power class.

If you would like to discuss your bevel gear or coupling application with a Gleason representative, please contact us.



With Curvic couplings complex machine parts can be made in several small units, reducing machining time, simplifying final assembly, and cutting over-all manufacturing costs.

GLEASON WORKS

1000 UNIVERSITY AVE., ROCHESTER 3, N. Y.

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ELECTRONICS.... HYDRAULICS.... HEAT TRANSFER.... LUBRICATION

NUCLEONICS.... SONICS.... COOLANTS.... DIELECTRICS:

Monsanto Specialized Fluids and new FluiDesign Service can help you benefit from

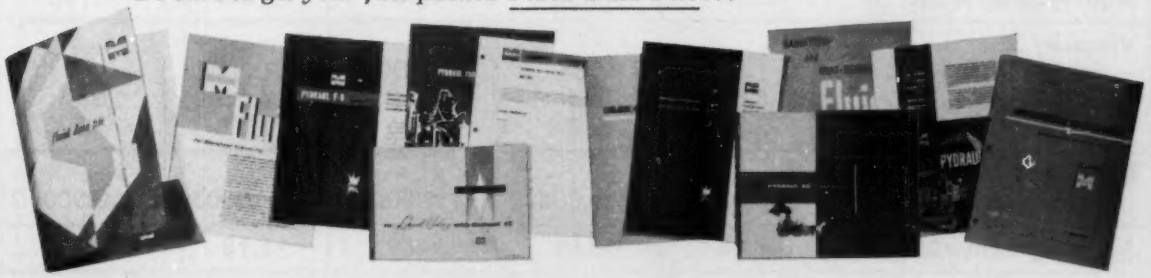
A RENAISSANCE IN ENGINEERING DESIGNS

Conventional fluids (water, oil) impose well-known restrictions on engineering designs. Heat, radiation, fire hazard, shear, electrical requirements, extreme pressure, friction—all cause problems—limit you in design flexibility, in imaginative thinking, in new ideas.

Monsanto's specialized synthetic fluids—chemically tailored to minimize many design restrictions in power transmission, lubrication, heat transfer, insulation, cooling—make new and improved designs practical. Spawned by advances in specialized fluid properties and broadening of fluid functions—a renaissance in engineering concepts is starting now. These specialized fluids open new design opportunities for your exploration.

Monsanto's new FluiDesign Service—established to help you meet your needs best from the capabilities of some thirty specialized fluids—can give you valuable guidance at the outset of your design exploration and engineering planning. For example, the next two pages provide you with the FluiDesign Service Report, "Heat-Stable Fluids for *Critical* Thermal Conditions." Among the thermally stable and radiation-resistant fluids described, one or more may allow you to engineer your next design for unequaled efficiency.

Be sure to get your fact-packed Fluid Data File...



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From Monsanto FluiDesign Service . . .

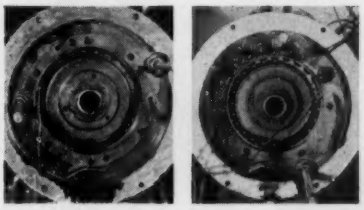
HEAT-STABLE FLUIDS FOR CRITICAL THERMAL CONDITIONS

Rapid evaporation, variable viscosity, foaming, cavitation, and "gunking up" at high temperatures are shortcomings of many common functional fluids. They are symptoms of thermal instability that bedevils operation of equipment.

Monsanto has developed a whole series of heat-stable synthetic fluids that eliminate many restrictions on new equipment design—*for applications that demand optimum thermal stability.* These chemically synthesized fluids include silicate esters, chlorinated polyphenyls, polyphenyls, and polyphenyl ethers. Some perform at freezing temperatures below *minus* 65° F. Others withstand continuous scorching heat above 800° F. Many are fire-resistant, radiation-resistant, noncorrosive. They give long, low-maintenance service as heat transferants, as lubricants, as hydraulic fluids, as dielectrics in high-temperature applications.

Monsanto Fluid	OS-59	Coolanol 35	Coolanol 45	Aroclor 1221	Aroclor 1232	
Properties						
Max. bulk temp., °F. long term	500	400	400	600	600	
Radiation resistant . . .	No	No	No	No	No	
Thermal conductivity Btu/hr./ft.²/ft./°F. . .	0.077	0.079	0.080	0.067	0.063	
Specific heat, @ 25°C.. .	0.45	0.45	0.45	0.33	0.31	
Boiling point, °F. @ 760 mm. Hg	>700	>600	>700	527	554	
Flash point, °F. Cleveland Open Cup .	370	370	370	295	308	
Fire point, °F. Cleveland Open Cup .	435	430	430	349	460	
Auto-ignition temp., °F. .	. . .	655	700	>1000	>1100	
Viscosity, cs.						
@ −65°F.	1380	934	2400	. . .	. . .	
@ 100°F.	6.8	6.5	12.2	4.6	6.9	
@ 210°F.	2.2	2.2	3.95	<1.8	<1.8	
Coefficient of thermal expansion, per °F. . .	0.00046	0.00047	0.00048	0.00039	0.00040	
Specific gravity @25°/25°C.	0.88	0.89	0.89	1.18	1.26	

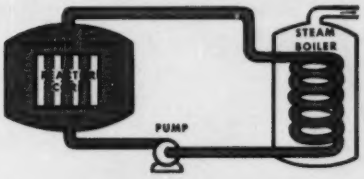
Monsanto offers a family of unique new fluids—*polyphenyl ethers*—that outperform all other known lubricants and hydraulic fluids in high-temperature operations. Their *useful* temperature range exceeds other thermally stable fluids by 100° to 400° F. The polyphenyl ethers not only match the lubricity and viscosity indices of other good lubricants, but also possess superior hydrolytic stability.



Photos courtesy of Pratt & Whitney Aircraft

Test rig parts for evaluating properties of jet engine lubricants show how a polyphenyl ether (left) leaves the rig parts clean, free of deposits, and with no evidence of wear. Photo at right shows deposits and general condition of parts using one of the best synthetic lubricants available prior to development of polyphenyl ethers. Both tests were run at a bearing temperature of 500° F. for 100 hours at a speed of 10,000 rpm.

Some Monsanto fluids are so radiation-resistant and thermally stable that they are used in the torturous environment of the nuclear reactor. Under an A.E.C. contract to develop low-cost electricity from nuclear power, Atomics International designed and built an experimental reactor at Arco, Idaho . . . using Monsanto terphenyl compounds as the coolant-moderator and heat-transfer agent. Nearly three



years of testing indicate that these stable Monsanto fluids can successfully and economically transfer the tremendous heat of the "nuclear furnace" to steam generators.

Check the fluids described below for application in equipment you are using or developing. Monsanto can supply you with a thermally stable fluid to solve virtually any critical problem of high heat or radiation. By advance planning with Monsanto FluiDesign Service, it is possible to "chemically tailor" a stable synthetic fluid to your precise needs.

Samples of the fluids shown will be sent to you for evaluation on request. Please specify the particular fluid that interests you and state the nature of the application, so that pertinent details can be sent to you. For further information on available fluids, request a copy of FluiDesign Service's FLUID DATA FILE. Simply write on your company letterhead.

HB-40, Aroclor, Coolanol, Santowax: Monsanto T.M.s, Reg. U. S. Pat. Off.

Monsanto

Monsanto Chemical Company
Organic Chemicals Division
FluiDesign Service, Dept. 2705-A
St. Louis 66 Missouri

	Aroclor 1242	Aroclor 1248	Aroclor 1254	Aroclor 1260	OS-124 (polyphenyl ether)	HB-40	Santowax R
	600	600	600	600	800	800	> 750
	No	No	No	No	Yes	Yes	Yes
	0.058	0.057	0.054	0.051	0.077	0.072	0.063
	0.29	0.27	0.26	0.26	0.34	0.45	0.50
	617	644	689	725	982	683	687
	360	379	None	None	550	345	375
	> 610	> 640	> 662	> 698	660	385	460
	> 1200	> 1200	> 1200	> 1200	1135	> 1000	> 1000
	. . . 17.2 2.5	. . . 45.3 3.2	. . . 46.4 6.14	 75	. . . 363 13.2	. . . 29 3.9	. . . .
	0.00038	0.00039	0.00037	0.00037	0.00033	0.00041	0.00052
	1.38	1.45	1.54	1.62	1.204	1.002	0.955

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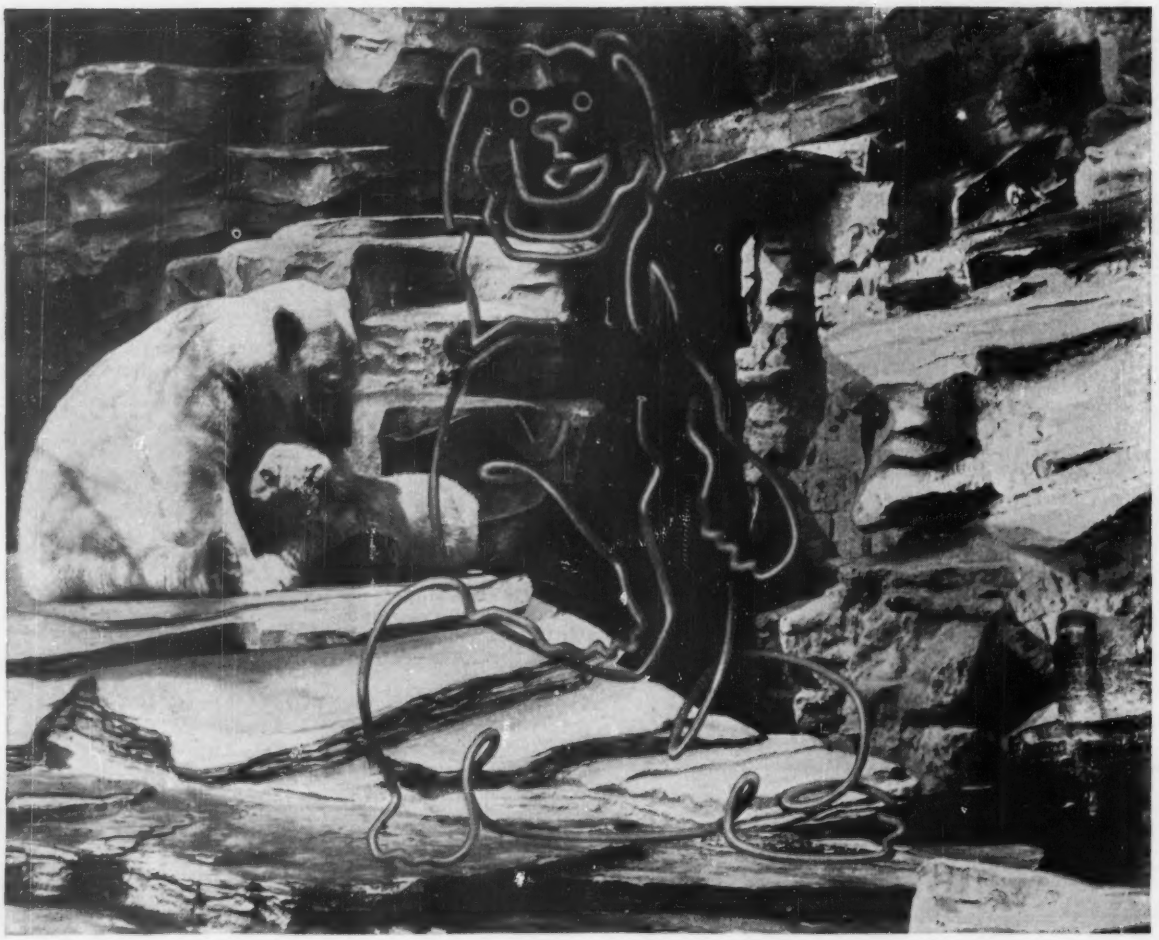
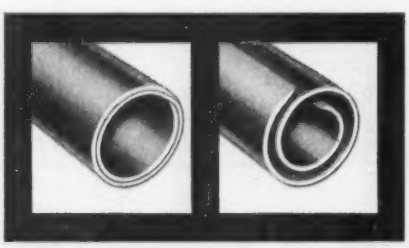


Bundy can mass-fabricate practically anything

Almost any tubing component you may need—simple or complex—can be mass-fabricated by Bundy. If you are planning a new product, Bundy specialists will work with you at any time to iron out kinks in tubing problems. Or perhaps Bundy engineers can help you simplify the design—and cut costs—of existing tubing components. And when you specify Bundy you get superior tubing. Bundyweld® meets ASTM 254; Government Specification MIL-T-3520, Type III. Phone, write or wire: Bundy Tubing Company, Detroit 14, Michigan.



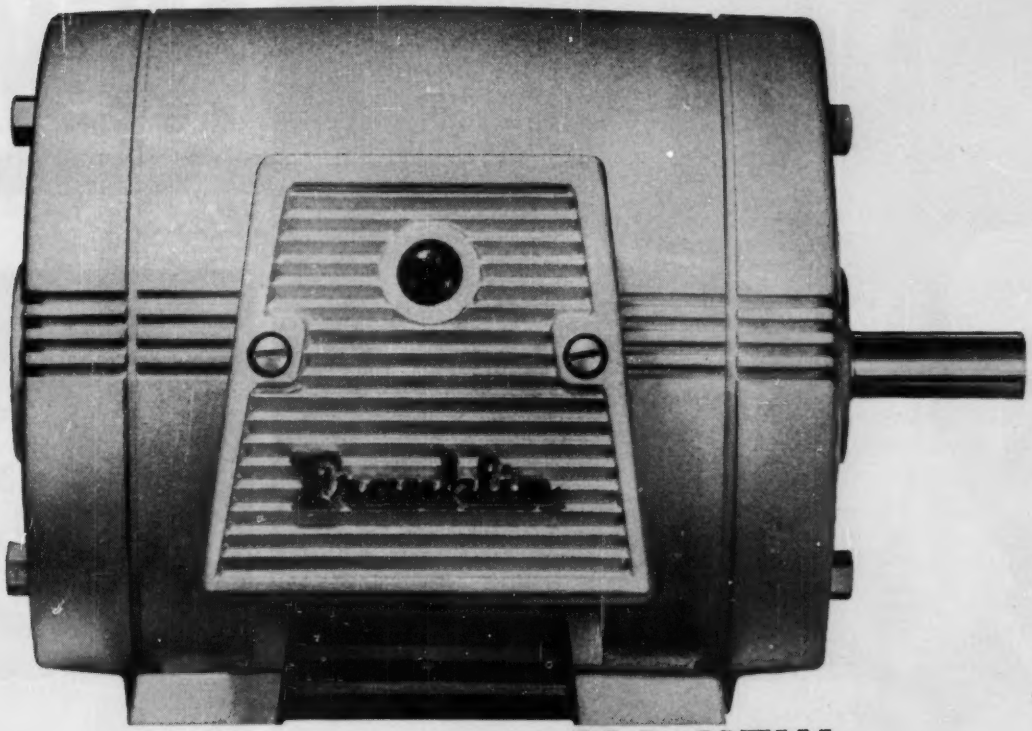
* * *

Bundyweld, double-walled from a single copper-plated steel strip, is metallurgically bonded through 360° of wall contact. It is lightweight, uniformly smooth and easily fabricated... has remarkably high bursting and fatigue strengths. Sizes up to 5/8" O.D.

BUNDY® TUBING COMPANY

DETROIT 14, MICH. • WINCHESTER, KY. • HOMETOWN, PA.

WORLD'S LARGEST PRODUCER OF SMALL-DIAMETER TUBING. AFFILIATED PLANTS IN AUSTRALIA, BRAZIL, ENGLAND, FRANCE, GERMANY, ITALY, JAPAN.

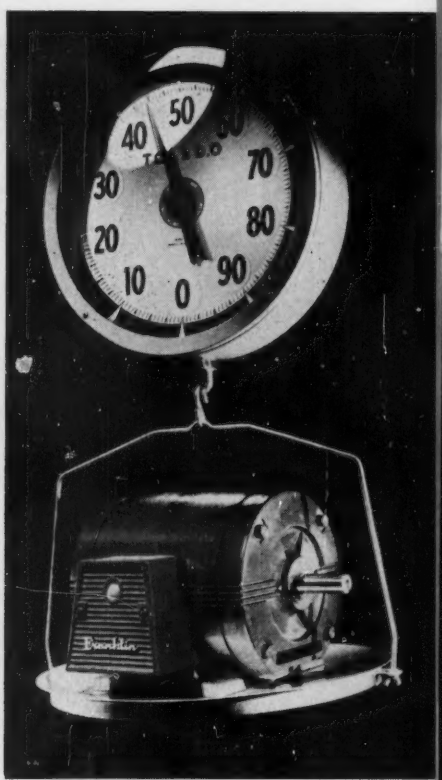


ALL NEW FRANKLIN STANDARD MOTORS WEIGH UP TO 30% LESS THAN ORDINARY INTEGRAL MOTORS

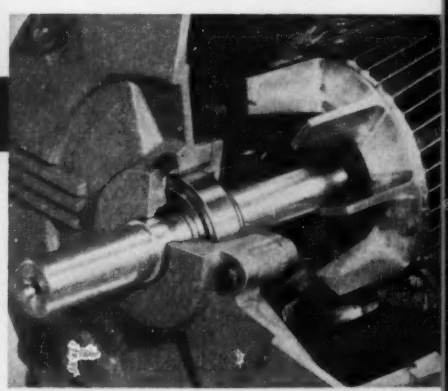
Read about this engineering accomplishment on the next two pages ... Also on the next page—news of a contest for design engineers only!!

Circle 427 on Page 19

NEW!



ALUMINUM CONSTRUCTION of the new Franklin motor gives the designer terrific weight advantages, plus faster heat dispersion and freedom from rust and corrosion. Strong, too.



PRELUBRICATED AND DOUBLE SHIELDED BEARINGS absolutely exclude all contaminants, eliminate the chief cause of motor bearing failure. Internal labyrinth seal keeps the grease in the bearings, out of the windings.

Franklin Integral Motors are made of Aluminum...

YET THEY'RE STRUCTURALLY STRONGER THAN COMPARABLE CAST-IRON MOTORS!

Here's news of a new, feather-weight motor you can apply *now* to your product.

Franklin Electric has designed an integral HP motor that gives you the light weight of aluminum . . . with a shock resistance greater than cast iron!

Aluminum frame, end-bells, rotor, and conduit box are combined to give you an average of *30% less weight* per motor rating.

You actually design weight *out* of your product by using this new, lighter motor. You'll need less bracing and support. And the Franklin lightweight is far easier to handle on your assembly lines. Less worker fatigue, faster assemblies. What's more, your shipping costs go down automatically with the over-all weight reduction!

Aluminum has other advantages for you, too: greater thermal conductivity for cooler running, and a high resistance to rust and corrosion.

How many times could you have used these other Franklin features:

1. Pre-packed, double shielded bearings that absolutely exclude contaminants (chief cause of bearing failures in ordinary motors). There's an unusual labyrinth seal on the shaft that keeps grease in the bearings, not on the shaft. And a grease reservoir that practically eliminates the need for regreasing.
2. Quick-connect terminal board that arrives pre-connected to your specified voltage. No more taping and wiring. Terminal connectors make line connections in a matter of seconds.
3. Two-year guarantee from date of manufacture.
4. Inherent protector space *built-in* to the conduit box. The clean lines of this motor will stay clean. No add-ons.
5. Identical NEMA single and polyphase motor frame sizes. They're completely interchangeable, so you need carry no extra bases in stock.

And plenty more designer-requested features that can help you cut costs and increase the efficiency of your motor-driven product. For the complete story, just send in coupon below for a free, full-color brochure which explains this new motor line in detail. And while you're at it, enter the Franklin "Name the Aluminum Motor" contest explained below. Send in the coupon today.

Franklin® Electric Co., Inc.
BLUFFTON, INDIANA

Name the Aluminum Motor Contest... for Design Engineers only!

WIN A FULLY EQUIPPED STARCRAFT ALUMINUM BOAT AND EVINRUDE MOTOR!

Send your suggestion for a name for the all-new Franklin aluminum motor on the coupon at right. First prize—a 16 ft. Starcraft aluminum "Jupiter" runabout and a 40 h.p. Evinrude outboard motor. Twenty additional runner-up prizes of deluxe aluminum golf carts. Enter now, while the coupon is right in front of you. Here's all you have to do:

1. Send to Franklin Electric Company, Inc., your name suggestion, which reflects either a use or a feature of the motor. For example: OEM motor, Alumaline motors, etc. Send as many names as you please.
2. Prize winners will be chosen by an impartial panel of judges who are not employees of Franklin Electric Company, Inc.
3. Your entry must be in by February 28, 1961.
4. There's nothing to buy—just send your name suggestion.
5. That's absolutely all there is to it. In addition, your entry will automatically bring you a full-color informative brochure on the new Franklin aluminum motor.
6. Employees of Franklin Electric and its advertising agency are not eligible to participate as contestants. Contest offer not valid in states which prohibit such contests.

SEND YOUR ENTRY TO:
Franklin Electric Company, Inc.
Name-the-Aluminum Motor Contest
Bluffton, Indiana

Name _____ Title _____

Company _____

Address _____

City _____ State _____

Suggested name for the new Franklin motor:

_____ D

Circle 427 on Page 19

You get these benefits...

- * prompt delivery
- * competitive pricing
- * any external mounting to meet your requirements

When you BUY

VICKERS HYDRAULIC CYLINDERS

Typical of custom designs that can be furnished readily from Vickers new cylinder facility is this model built with extra rigidity and strength at both rod and clevis ends to overcome side loadings. For added corrosion resistance, stainless steel clevis pins, piston rods, retaining screws and grease fittings are used.

Standard Models for Operation to 3000 psi

Choose the cylinder "outside" that's best for your installation—Vickers offers you a wide selection of standard mountings plus an almost unlimited range of special configurations. Alternate rod end threads . . . straight thread port connections . . . extra barrel lengths for bearing support . . . are among many available options.

- Working pressures to 3000 psi (non-shock)
- Hard chrome plated, ground and polished, high-strength alloy steel piston rods.
- Large ports hold pressure drop within desirable limits.
- Fast, accurate parts replacement is assured because all cylinders are individually registered.
- Honed barrels of heavy walled seamless tubing minimize friction and wear.
- Cushions can be provided—either head, rod or both ends.
- Your choice of automotive step-cut piston rings for maximum life or low friction "T" rings for applications requiring minimum leakage. Full size cast iron piston for maximum bearing support with either type seal.
- Synthetic rubber wiper ring is standard—metallic wipers available.
- Two large wrench flats on rod are standard—additional flats available on request.
- Fully meet JIC specifications.

New, separate plant facilities—devoted exclusively to the design and manufacture of hydraulic cylinders—assure prompt individual attention to your orders. Service stocks are maintained at all Vickers warehouses in the U.S. and Canada. For more application data and installation dimensions, call or write today for Bulletin 60-68

VICKERS INCORPORATED

DIVISION OF SPERRY RAND CORPORATION

Machinery Hydraulics Division

ADMINISTRATIVE and ENGINEERING CENTER

Department 1430 • Detroit 32, Michigan

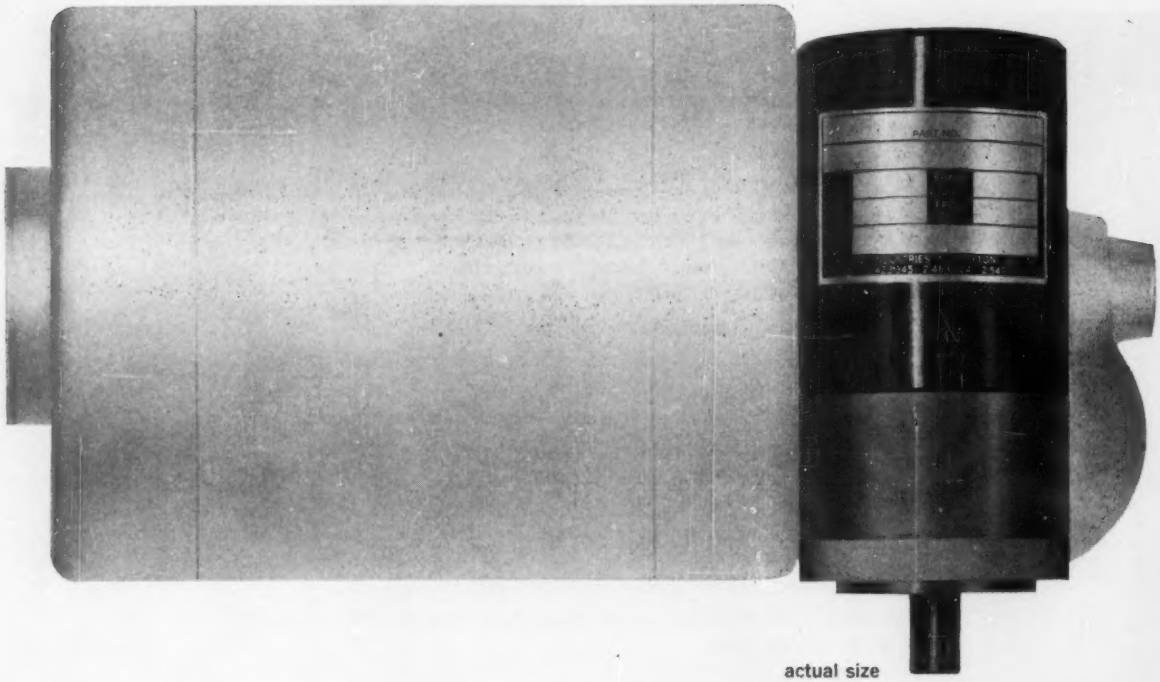
FOR PROMPT SERVICE CALL:

DETROIT TOwnsend 8-0272	**CINCINNATI** MAin 1-1756	**INDIANAPOLIS** CLifford 3-3535	**PHILADELPHIA (Area)** LOwell 6-7900	**SAN FRANCISCO (Area)** ATlantic 4-7106
ATLANTA TRinity 4-0187 2-0837	**CLEVELAND** EVergreen 2-3366	**LOS ANGELES (Area)** ORegon 8-2503	**PITTSBURGH (Area)** LOcust 1-3504	**SEATTLE** MUtual 2-6950
BIRMINGHAM TReemont 1-9531	**GRAND RAPIDS** GLendale 6-1146	**MILWAUKEE** UPtown 1-0860	**ROCHESTER** LOcust 2-5384	**ST. LOUIS** PArkview 1-4311
CHICAGO (Area) POrter 6-2900	**HOUSTON** JAckson 2-9623	**NEW YORK (Area)** DRexel 6-3500	**ROCKFORD** WOodland 2-0615	**WORCESTER** SWift 8-3706

6903

Standard Models for Operation to 3000 psi

Circle 430 on Page 19



actual size

GEARMOTORS 3/4 SMALLER

The Globe a.c. gearmotor you see superimposed against a conventional right-angle gearmotor will give your product major advantages: Globe's version is much smaller than the big style, is interchangeable with slight mounting changes, produces the same torque, and should run 5 to 7 times as long without maintenance, even with high inertia loads. Study the picture above with **your** application in mind.

Furthermore, Globe gives you a choice of 101 **standard** planetary gear ratios, and any special ratios or other features you need. The Globe gearmotor is competitive in cost even though it meets military specifications. If you don't have rigid environmental requirements Globe can furnish a commercial version in production quantities at a saving to you. If you design with induction or hysteresis synchronous gearmotors—investigate now.

Globe has available for **immediate** shipment prototypes of the Type FC, 115v. a.c., 60 cycle synchronous motor in the following gear ratios: 352.6 to 1 (10.2 rpm, 160 oz. in. out), and 27.94 to 1 (64.4 rpm., 19 oz. in. out). Other variations, including d.c., about 4 week delivery. Please request Bulletin FCB from Globe Industries, Inc., 1784 Stanley Avenue, Dayton 4, Ohio.

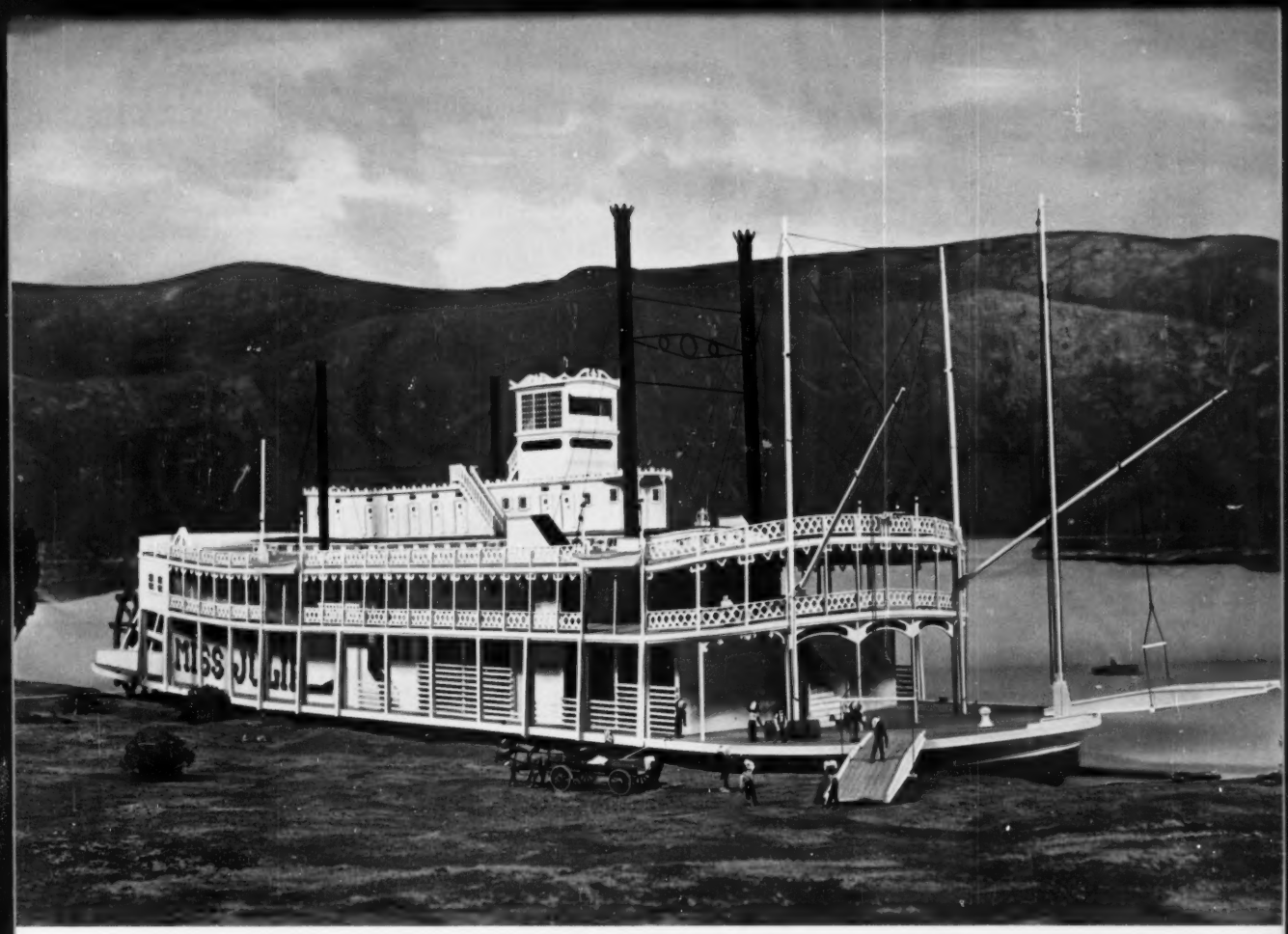
GLOBE

GLOBE INDUSTRIES, INC.

PRECISION MINIATURE A.C. & D.C. MOTORS, ACTUATORS, TIMERS, STEPPERS, BLOWERS, FANS, MOTORIZED DEVICES

Circle 431 on Page 19

Circle 432 on Page 19→



OHIO Special Quality Tubing makes muscles that never tire

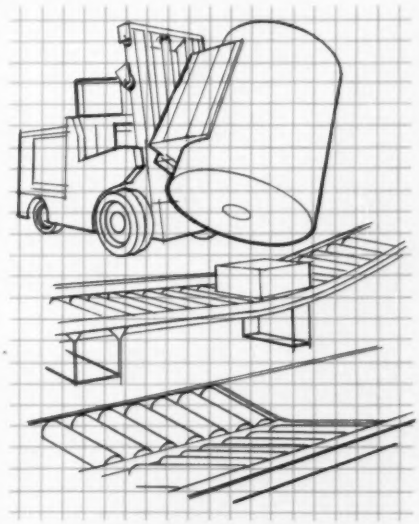
Strength, weight and cost advantages of OHIO Special Quality Tubing make it ideal for use in materials handling equipment — the modern lift trucks, belt and roller conveyor systems that provide the heft and muscle to move materials.

You can strengthen your product, too, if you weigh these important facts. OHIO Tubing is always the exact tubing you need because OHIO Tubing is CUSTOM MADE for your product. Your order is manufactured to your own specifications to produce steel tubing especially for your application — the precise grade, analysis, size, shape, special anneal and tolerances best suited to your needs.

Ohio Seamless Tube produces both seamless and electric welded steel tubing — is prepared to form many finished or semi-finished tubular parts to your designs.

To get the most from your next steel tubing order, specify OHIO Special Quality Tubing. Contact your nearest Ohio Seamless representative, or send part drawings to the plant at Shelby, Ohio — Birthplace of the Seamless Steel Tube Industry in America.

A-3281A



Model illustrated built to 3.5 mm scale.

OHIO

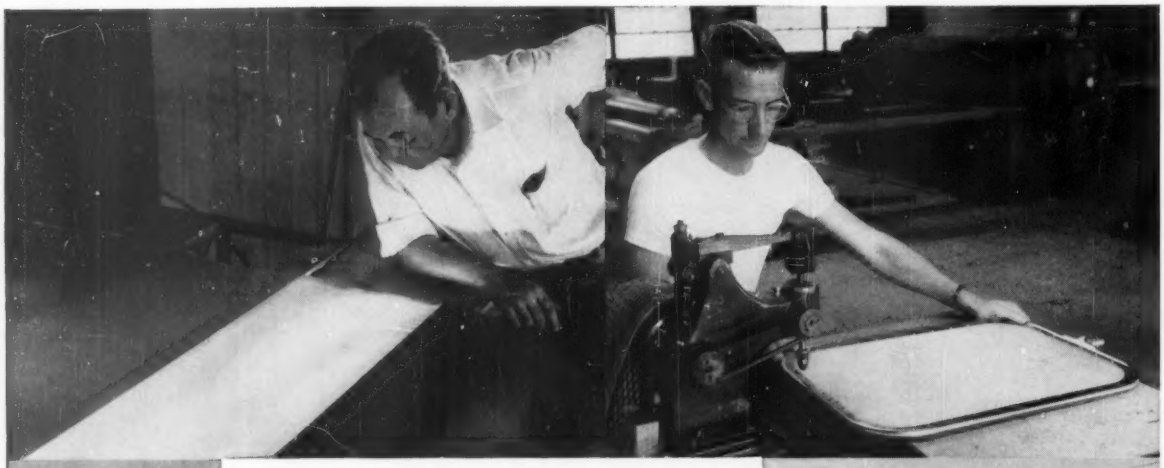
OHIO SEAMLESS TUBE

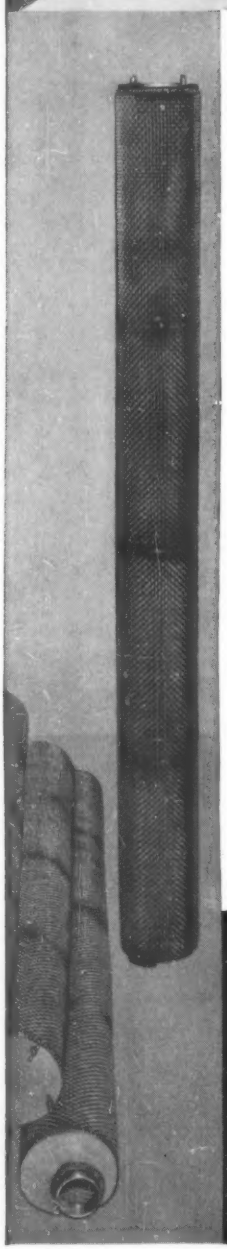
Division of Copperweld Steel Company • **SHELBY, OHIO**

Seamless and Electric Resistance Welded Steel Tubing • Fabricating and Forging

SALES OFFICES: Birmingham, Charlotte, Chicago (Oak Park), Cleveland, Dayton, Denver, Detroit (Huntington Woods), Houston, Kansas City, Los Angeles (Lynwood), Miami, Moline, New Orleans (Chalmette), New York, Philadelphia (Wynnewood), Pittsburgh, Richmond, Rochester, St. Louis, St. Paul, Salt Lake City, Seattle, Tulsa, Wichita

CANADA: Railway & Power Engr. Corp., Ltd. EXPORT: Copperweld Steel International Company, 225 Broadway, New York 7, New York





Who cares about your Wire Cloth Fabrications?

CAMBRIDGE does . . .

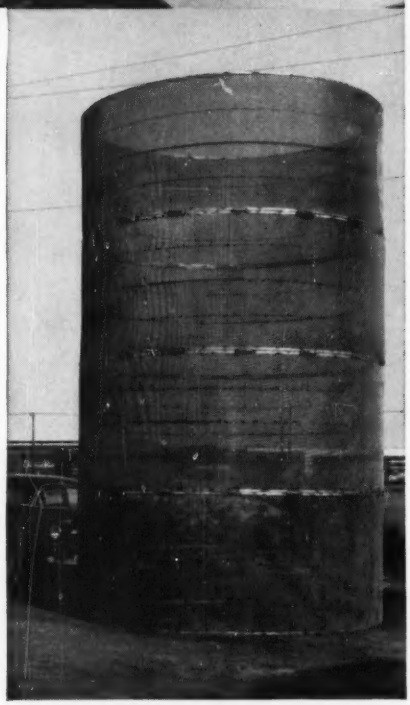
that's why you automatically get service with your order . . . whether you need dozens of midget strainers or a single giant-sized retaining screen.

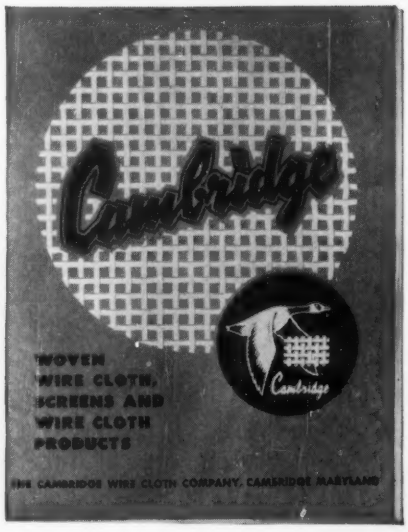
Careful, competent workmanship and constant inspection assure you of quality . . . modern machinery and accurate scheduling assure you of prompt delivery. And, a Cambridge Field Engineer follows up your order to make sure our product is giving you the best possible service. Let us quote on your next order for wire cloth fabrications. We manufacture wire cloth from any metal or alloy—including titanium—in nine basic weaves. We'll work from your prints or draw up prints for your approval. Call your Cambridge Field Engineer . . . he's listed in the yellow pages under "Wire Cloth". Or, write for FREE 94-PAGE CATALOG.

The Cambridge Wire Cloth Co.

Department N • Cambridge 12, Md.

Manufacturers of Wire Cloth, Metal-Mesh Conveyor Belts, Wire Cloth Fabrications





Circle 433 on Page 19

Fewer replacements, farther between

...with these LINK-BELT conveyor and elevator chains

LINK-BELT C CLASS CHAIN combines cast malleable center links with steel sidebars connected by steel pins. Broad tops and bottoms provide ample sliding surfaces for drag conveyors. Also available with Promal or "file-hard" Promal center links for extreme loads and abrasive wear. Promal is the special Link-Belt metal that lasts much longer . . . costs but little more.

LINK-BELT SS CLASS BUSHED CHAIN. If your conveyor or elevator must be lengthened, or load increase accommodated, you can install this all-steel chain in place of C Class *without changing sprockets!* It offers hardened joint bearing surfaces for greater wear resistance in heavy-duty conveying and elevating. Smooth, tough joint surfaces repel gritty materials, prevent packing, and resist abrasion.

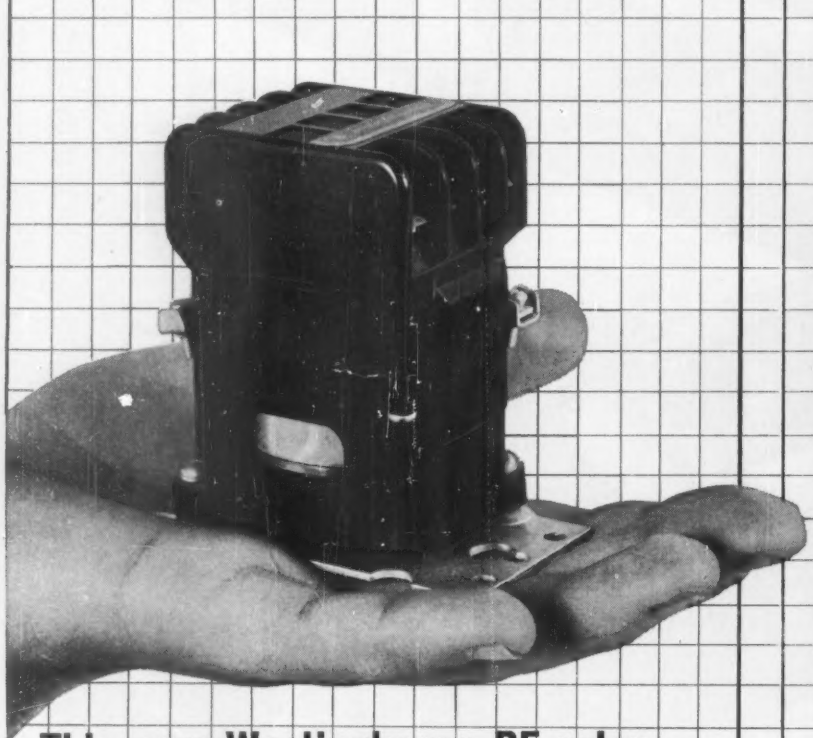
Full information on these chains . . . plus a broad line of attachments — is contained in Catalog 1050. Get your copy by writing direct . . . or call your nearest Link-Belt office, listed under CHAINS in the yellow pages of your local Phone Directory.

LINK-BELT

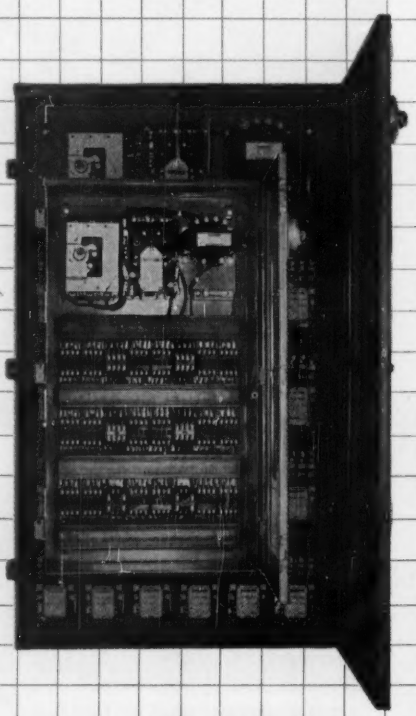
CHAINS AND SPROCKETS

LINK-BELT COMPANY: Executive Offices, Prudential Plaza, Chicago 1. To Serve Industry There Are Link-Belt Plants, Sales Offices and Stock Carrying Distributors in All Principal Cities. Export Office, New York 7; Australia, Marrickville (Sydney); Brazil, Sao Paulo; Canada, Scarboro (Toronto 13); South Africa, Springs.
Representatives Throughout the World. 15,066

Circle 434 on Page 19

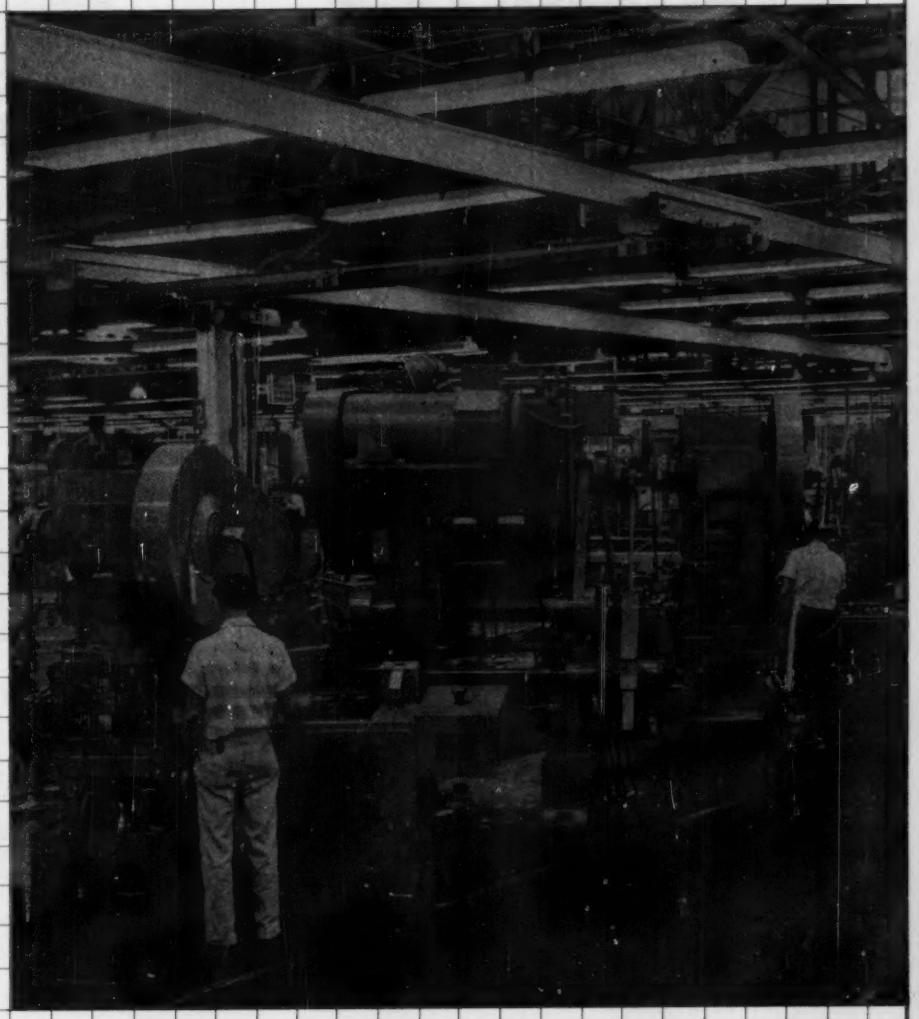


This new Westinghouse BF relay . . .



saves inches here . . .

This new Westinghouse BF relay is small and can be butted one against the other so that your control panels can be reduced in size as much as 50%. Result: valuable plant floor space available for additional machines. Because the relay is specifically designed for automated machine tools, you cut installed costs more than 20%. And since this relay is in stock, you get these savings NOW.



feet here . . .

Want more information on the 6-amp, 300-volt BF and its companion, the 10-amp, 600-volt AF? Contact your nearest Westinghouse representative . . . or write Westinghouse Electric Corporation, Standard Control Division, Beaver, Pa. J-80321-R

You can be sure...if it's **Westinghouse**

Circle 435 on Page 19

honesty

the bees and the drones

Some bees built their comb in a hollow tree, but the drones took possession and claimed it for their own. The case was brought before the wise old wasp, who was to judge the rightful owner. // "The only way to be sure who is the owner," ruled the wasp, "is for each party to build a new comb. Whoever makes a comb most like the one in dispute, is the real owner." The bees agreed, but the drones refused. // The wise wasp then handed down his verdict: "It is clear now who made the comb, and who cannot make it. It belongs to the bees."

moral: Trial is the best test of performance.

We'd like you to give Hydro-Line cylinders a trial. They don't mind hard work. In fact, these heavy-duty cylinders are designed especially for hydraulic applications to 5000 psi, air operations to 200 psi.

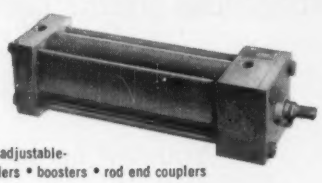
Whatever you are building, there is a Hydro-Line cylinder to help your machines complete the job more efficiently. Standard stock cylinders usually will be your best decision. They have all catalog stock dimensions, give you 10% price savings over custom cylinders, and are delivered "off the shelf."

Of course, if you need a modified cylinder, your Hydro-Line representative will help you judge the proper cylinder design for the particular job. Either way, you can be sure the right cylinder design is helping you increase productivity.

Look in *Sweet's Product Design File* for standard dimensions of stock cylinders and the address of your nearest Hydro-Line representative. Then ask him for the cylinder design that belongs on your machines. Or, phone TRemont 7-5758 to contact the factory.

HYDRO-LINE

HYDRO-LINE CYLINDERS



5602 PIKE ROAD, ROCKFORD, ILLINOIS, manufacturers of:
high- and low-pressure hydraulic cylinders • heavy-duty air cylinders • adjustable-stroke cylinders • dispensing cylinders • intensifiers • single-acting cylinders • boosters • rod end couplers

Circle 436 on Page 19

Mr. Diserens (left) inspects a "Cronaflex" reduction with Robt. E. Thomas of Arrow Blue Company, Cincinnati Shaper Company's blueprinter.

60 YEAR OLD STORAGE PROBLEM SOLVED!

Versatile *Cronaflex*® Makes Possible Money-Saving Miniaturization Program

Finding a way to reorganize and consolidate a 60-year accumulation of engineering drawings posed a real problem for Cincinnati Shaper Company—until the firm learned of "Cronaflex"* Engineering Reproduction Films. As Chief Engineer Ralph Diserens tells it:

"By making reductions on 'Cronaflex' of all usable drawings, we've cut storage needs *75 per cent without the expense of costly new equipment or changes in present methods of operation.* The superior matte surface of 'Cronaflex' makes drafting on the reductions easy. And prints made from them are as easy to read as those made from originals —if not easier. The 'Cronaflex' reductions are also a lot more durable and take repeated handling without damage."

Cincinnati Shaper Co. has now standardized on "Cronaflex" for all its engineering reproduction requirements. They estimate that total savings in terms of reduced drafting time, lower print costs, improved shop efficiency and reclamation of drawings that would otherwise have to be retraced—all made possible by "Cronaflex"—will pay for the program in eighteen months.

Concludes Mr. Diserens: "Not only was 'Cronaflex' the perfect solution to our problem, it was the *only* workable one!"

Clip and mail the coupon *now* for further details on this miniaturization program or for more information on how "Cronaflex" can help you step up efficiency and cut costs.

** Du Pont's registered trademark for its engineering reproduction films*

DU PONT
REG. U.S. PAT. OFF.

BETTER THINGS FOR BETTER LIVING . . . *THROUGH CHEMISTRY*

E. I. du Pont de Nemours & Co. (Inc.), Photo Products Dept. MD-12, Wilmington 98, Del.

I am interested in further information on:

☐ Miniaturization Program of Cincinnati Shaper Company

☐ The Full Line of "Cronaflex" Engineering Reproduction Films

Name_____

Firm_____

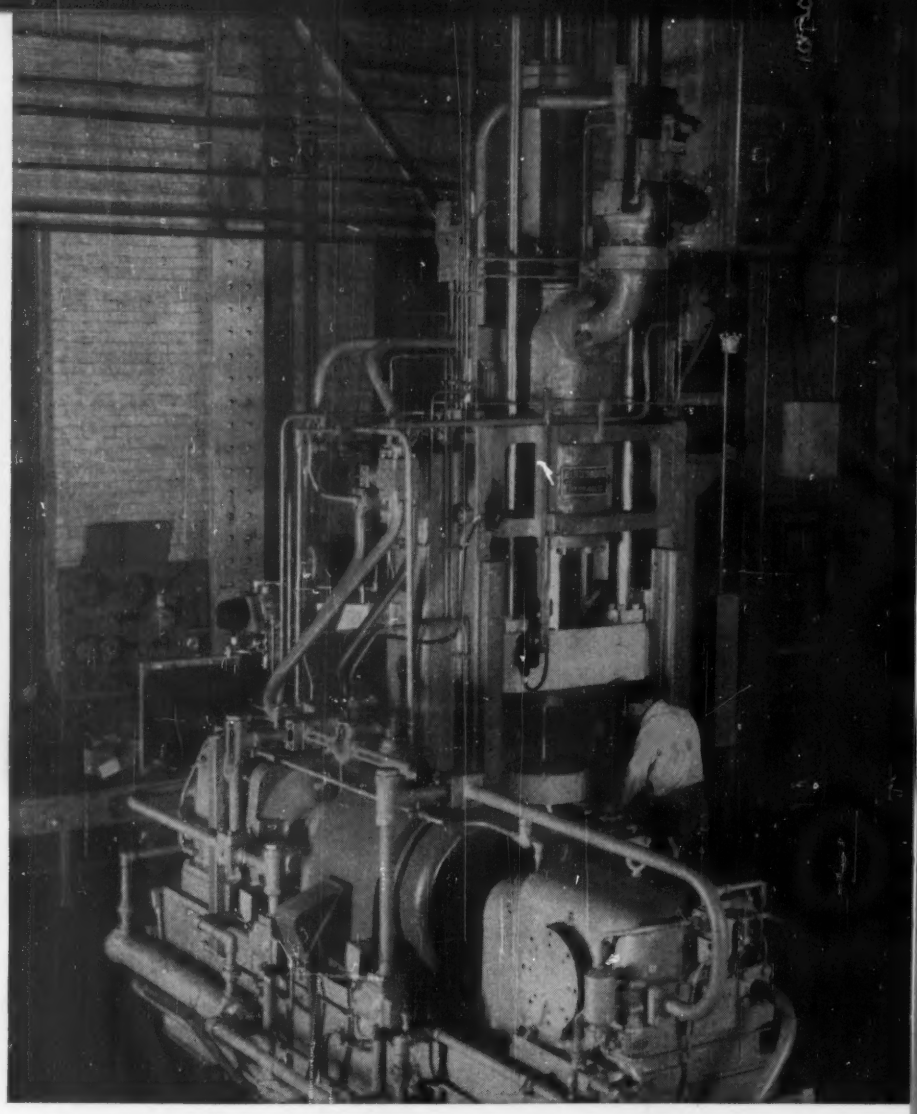
Address_____

City_____ Zone_____ State_____

Circle 437 on Page 19

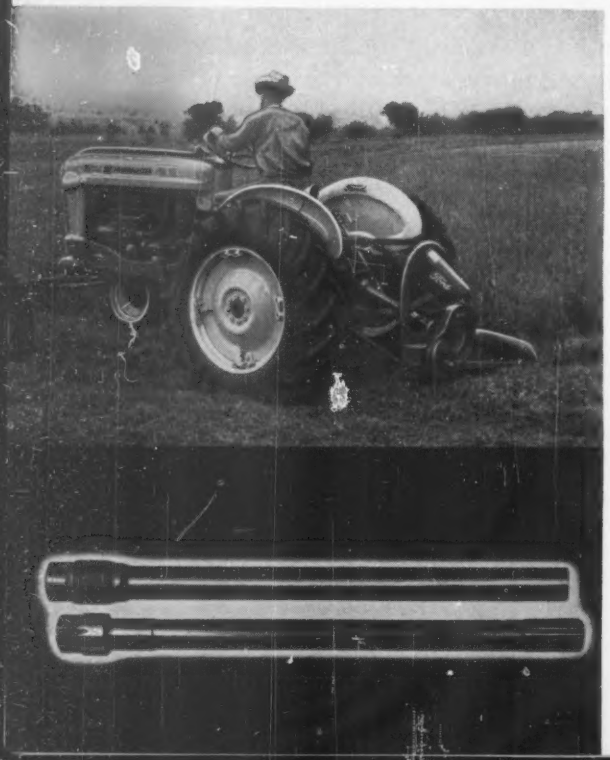
Steel

Strong,
Modern,
Dependable



This 500-ton hydraulically operated press built by Birdsboro Steel Foundry & Machine Company, Birdsboro, Pa., and featuring Republic ELECTRUNITE Hydraulic Fluid Line Tubing, is used by a leading research center for deep drawing, extruding, or planishing metals.

Circle 438 on Page 19

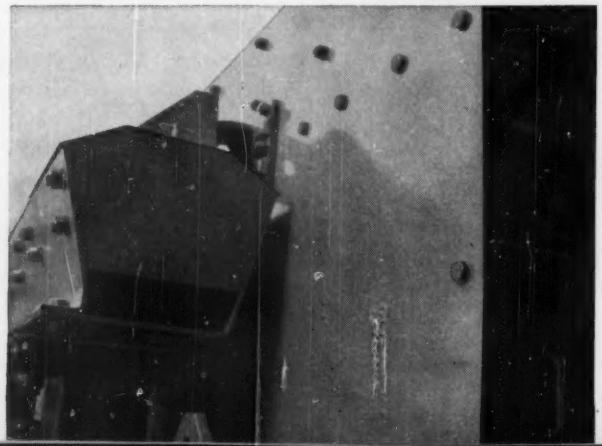


REPUBLIC DIE-FORM CUTS PRODUCTION COSTS. Ford Tractor Power Take-Off Counter-Shaft costs less to produce using a Republic Die-Form Blank, as compared to previous materials. Because Republic Die-Form Blanks closely approximate the completed part, they minimize required machining and reduce handling costs. In addition, the nature of the Die-Form Process improves machinability of any given analysis, permitting further savings through use of higher speeds and feeds. Photo below shows a Die-Form Blank and the completed shaft as featured in the Ford Tractor. Write for Die-Form Folder ADV-746.

Circle 439 on Page 19

REPUBLIC CAP SCREWS PROTECT SHAKER SCREEN PERFORMANCE. Sorting and sizing ton after ton of jolting, jarring, abrasive material is all in a day's work for Ty-Rock Vibrating Screens, built by The W. S. Tyler Company, Cleveland, Ohio. Satisfactory performance under these brutal conditions not only requires design and manufacturing skill, but a thorough knowledge of materials. Maximum performance under all operating conditions is typical of Republic's complete line of top-quality Cap Screws. Send coupon for data.

Circle 440 on Page 19



Stubborn resistance to fatigue...

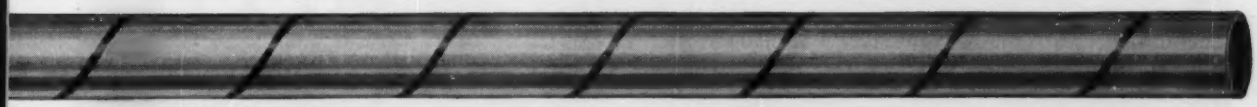
REPUBLIC ELECTRUNITE HYDRAULIC FLUID LINE TUBING

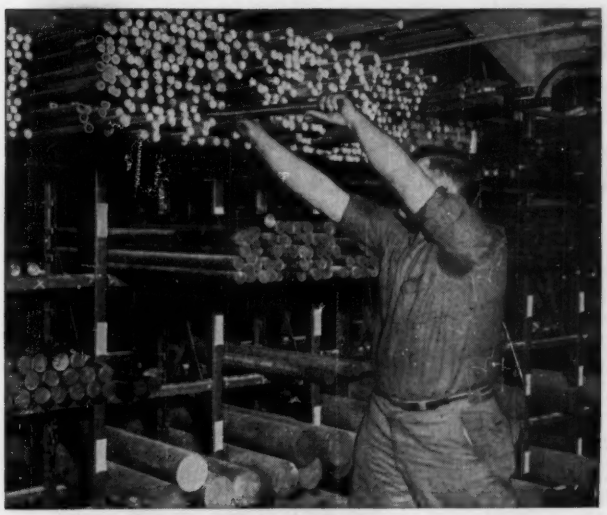
Machine tool builders and operators depend upon Republic ELECTRUNITE® Hydraulic Fluid Line Tubing for stubborn resistance to fatigue. Reason is the *consistent uniformity of concentricity* and mechanical properties of ELECTRUNITE welded steel tubing—characteristics that make this tube better able to withstand the vibrations of rapid multiple cycling.

This uniform concentricity—inherent in the ELECTRUNITE process—coupled with uniform heat treatment, insures uniform flaring characteristics. Uniform ductility assures easy bending. Both mean savings in original and in replacement installations.

You can recognize this best of all hydraulic line tubing by the blue spiral marking stenciled end-to-end on every length. It is your assurance of genuine ELECTRUNITE quality. The spiral marked tube is available in all sizes shown in JIC Standards, and is produced in a wider size range to Specification HL-1, which meets all JIC Standards test requirements.

Get all the facts. Discover how Republic ELECTRUNITE Hydraulic Fluid Line Tubing can substantially reduce maintenance costs in the most complicated installations. Call your Republic representative, or send coupon for additional information.





REPUBLIC WEDGE-LOCK PARTS® STORAGE UNITS are easy to load and unload from either side. And, the heavier the load, the tighter the grip, because patented Wedge-Lock construction includes a post that will not buckle, a concealed sway-proof joint, and a reinforced shelf that does not sag. Unlimited shelf arrangements. Capable of exceptionally high stacking. Republic Storage Engineering specialists will help you plan. Call your Republic representative today.

Circle 441 on Page 19

REPUBLIC STEEL

World's Widest Range of Standard Steels and Steel Products

REPUBLIC STEEL CORPORATION
DEPT. MD-9532-A
1441 REPUBLIC BUILDING • CLEVELAND 1, OHIO

Please send more information on the following products:

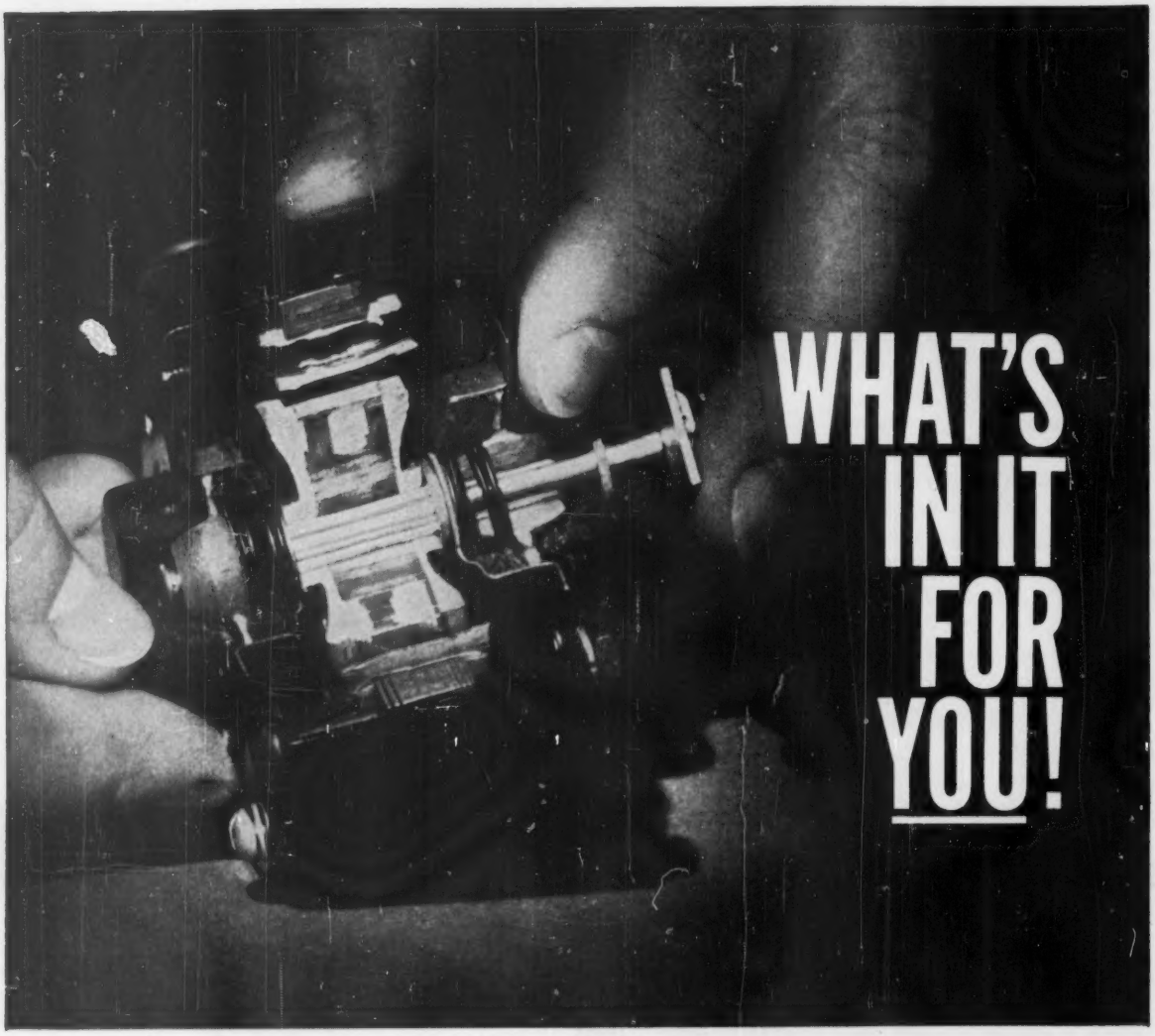
- ☐ Republic ELECTRUNITE Hydraulic Fluid Line Tubing
- ☐ Republic Die-Form—Folder ADV-746
- ☐ Republic Cap Screws ☐ Wedge-Lock Storage Units

Name_____ Title_____

Firm_____

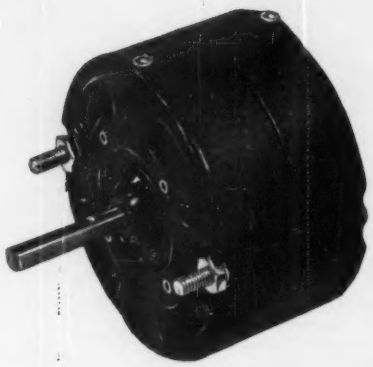
Address_____

City_____ Zone____ State_____



TWO-BEARING DESIGN MAKES THESE
EMERSON ELECTRIC MOTORS
Ideal for Refrigeration fan applications

Here's a *two-bearing* motor uniquely suited for refrigeration fan applications. It operates in any position . . . with a minimum of bearing load, vibration and friction. It starts easily at low temperatures because of EMERSON ELECTRIC'S self-oiling, self-aligning bearings that act as soft metal sponges and remove oil from the shaft journal as the motor cools. It lubricates without felt wick or shaft groove and requires less than one-third the oil needed in solid sleeve designs; yet, its oil storage capacity is equivalent to 60% *more* than most other refrigerator fan motors. The self-aligning feature completely eliminates tight shaft problems. EMERSON ELECTRIC will custom-engineer motors to meet *your* specific needs. Call us *today* . . . you'll like our way of doing business!



EMERSON ELECTRIC *of St. Louis • Since 1890*

DEPT M-24, 8100 FLORISSANT • ST. LOUIS 36, MO. • CO 1-1800

Can You Use BETTER Gray Iron Castings?

Eaton's Continuing Research and Development Programs Assure You the BEST—Engineered to Your Individual Needs

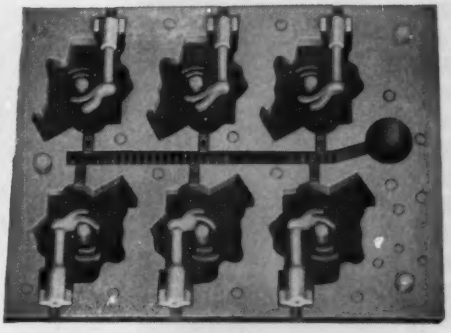
EATON PERMANENT MOLDING

Because of the denser, non-porous, homogeneous structure, Eaton Permanent Mold Castings meet critical quality requirements. The finer dispersion of graphite provides a better material where free machinability and accuracy are essential in critical machining operations. Eaton annealed gray iron castings are available in sizes from one tenth of a pound to fifty pounds.

EATON SHELL CORING

The Eaton process of Shell Coring in permanent mold and shell molded castings provides better internal surface finish and higher dimensional accuracy. Where more than ordinary quality and control of contour are required, the Eaton process offers distinct design advantages and greater uniformity in intricately cored sections.

EATON SHELL MOLDING



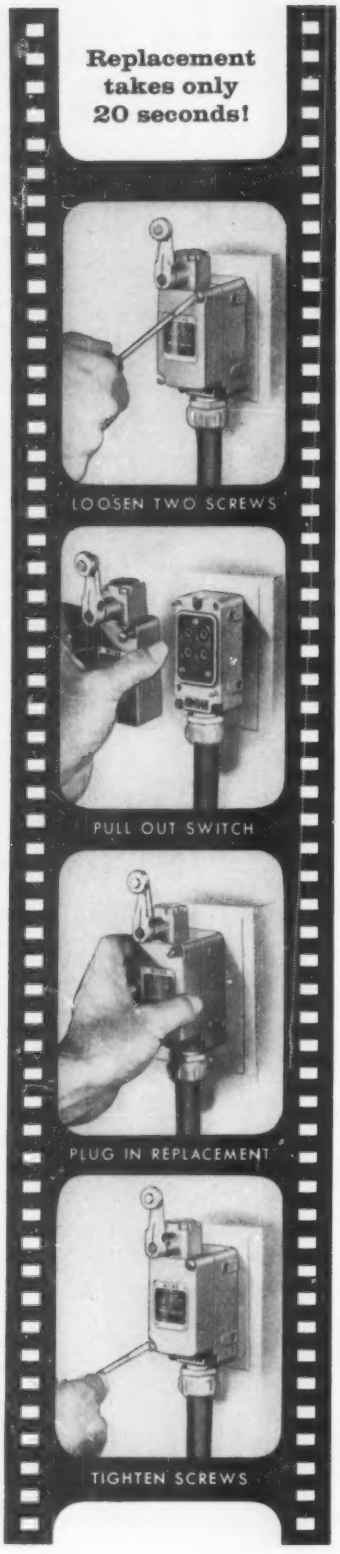
Eaton Shell Molding provides more closely controlled metallurgy and hardness for applications requiring pearlitic structures, close dimensional control, and complex designs and contours. Eaton Shell Mold Castings require less machining and finishing, with resulting savings in material, tooling, and shipping.

Send for Illustrated Descriptive Literature

EATON

FOUNDRY DIVISION
MANUFACTURING COMPANY
VASSAR, MICHIGAN

Circle 443 on Page 19



HOW MICRO SWITCH "Plug-in Limit" switches keep selling your machines...

The limit switches you specify on your machines can be salesmen or "sore spots." That's why more and more machine tool builders are depending on MICRO SWITCH reliability. And, MICRO now offers the most complete line of "Plug-in Limit" switches in the industry. These timesavers offer many special advantages when you specify them for your equipment:

1. MEASURABLE DOLLAR SAVINGS

Actual case histories prove the 20-second replacement time sometimes saves hundreds of dollars in production time over ordinary limit switches. The switching unit plugs in like a radio tube. Receptacle need not be removed. Your customers will appreciate this reduction of down time.

2. NINE DIFFERENT ACTUATORS

The one receptacle is designed for any of the nine styles of actuators. Flexibility for the design of your machine; adaptability later if necessary.

3. AUTOMATIC STATION CONTROL

Your customer will be able to automatically disconnect any station on his line by simply pulling out the correct MICRO "Plug-in Limit."

4. BEST SEALS AVAILABLE

The "O" Ring and gasket seals on these switches are the best available. Greater reliability for your machines, important because with customers, every actuation of a switch is a test of your equipment.

See the Yellow Pages for the location of the nearby MICRO SWITCH Branch Office and ask for the full story on how "200LS" Series "Plug-in Limit" switches can help sell your machines. Or, write for Catalog 84.

75 YEAR HONEYWELL PIONEERING THE FUTURE

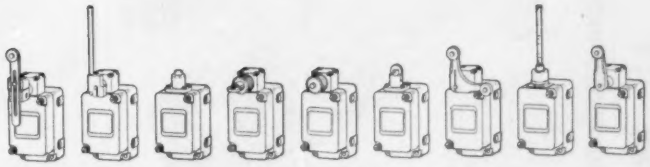
The "200LS" line has rugged terminal blocks with heavy No. 8 terminal screws for easy wiring and sturdy, molded barriers to protect plugs from damage. Operating head mounts in four positions.

5. FLEXIBLE MOUNTING

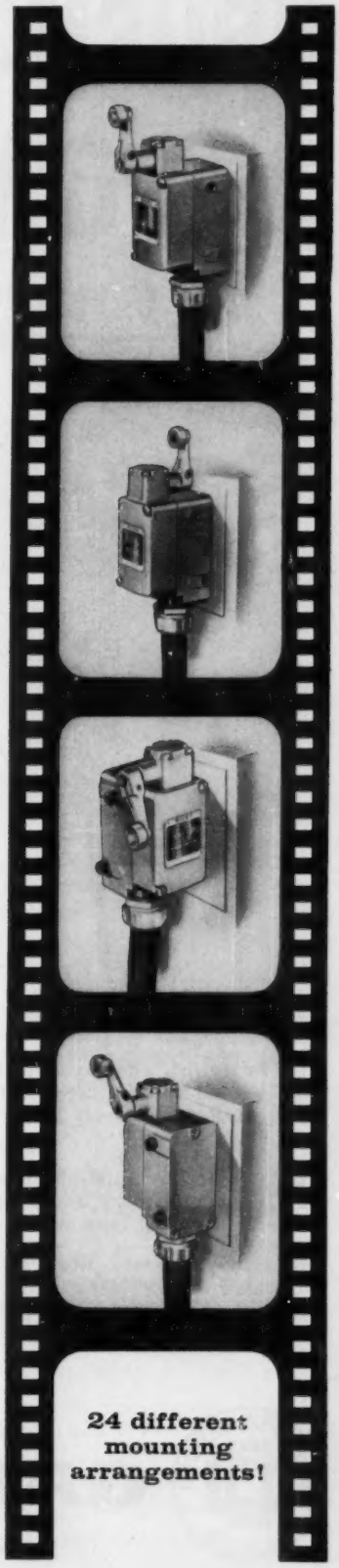
May be side-mounted or back-mounted for a possibility of 24 different mounting arrangements.

6. WIDER SELECTION

MICRO SWITCH offers many variations to fit specific needs. All have the same receptacle size for easy interchangeability. There's sure to be a model that fits your design needs.



MICRO SWITCH . . . FREEPORT, ILLINOIS
A division of Honeywell
In Canada: Honeywell Controls Limited, Toronto 17, Ontario



Honeywell
MICRO SWITCH Precision Switches

Circle 444 on Page 19

Add this "PUSH-PULL" POWER to your design

Anywhere you need "push-pull" power, design in a Gardner-Denver "Hoistractor"—small overhead cranes, conveyors and, of course, overhead hoists. This powerful, little prime mover rides any standard hoist beam . . . moves loads to five tons. Consult your Gardner-Denver air tool specialist for details or write for Bulletin 87-1.

Check this design

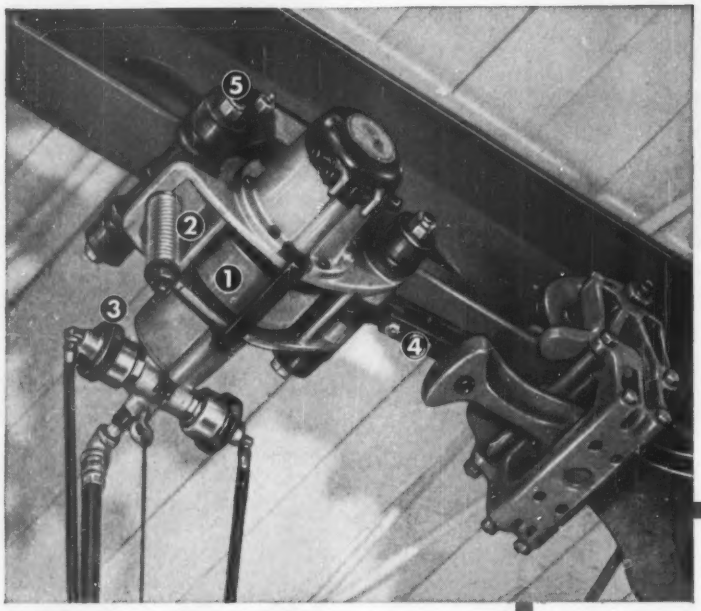
❶ **Neoprene drive wheel** (6″ dia.) gives 250-lb. drawbar pull against a beam for easy, high-speed moving of loads.

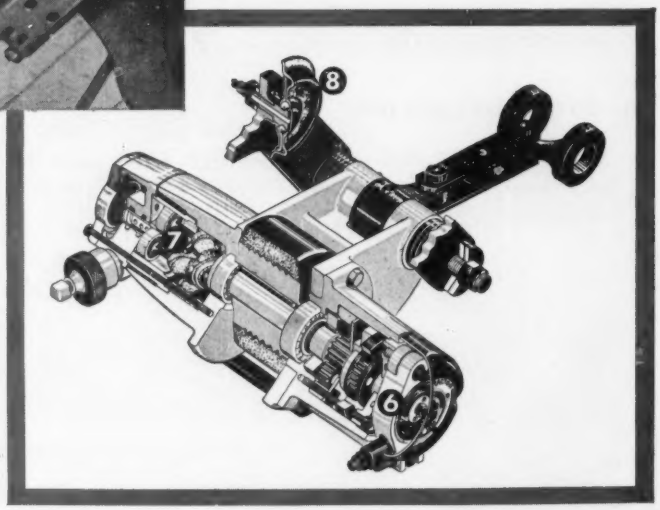
❷ **Drive-wheel load spring** maintains constant drive regardless of irregularities in track.

❸ **Sensitive air valves** for smooth operation at all speeds from a slow creep to maximum. Controlled from remote position.

❹ **Connecting drawbar** furnished. Two types available.

❺ **Easily adjusted** to meet standard beams in various widths by moving washers to outside plate.





❻ **Powerful, enclosed mechanical brake** easily adjusted. Not dependent on air supply —applied automatically in the event air supply fails.

❼ **Powered by axial-piston air motor.** Pulls 2-ton load at 70 fpm. Easily rolls loads to five tons. Motor can't burn out.

❽ **Heavy, pressed steel wheels** carburized and hardened for wear resistance. Deep flanges prevent wheels from climbing track. Ball bearings at all load points.

EQUIPMENT TODAY FOR THE CHALLENGE OF TOMORROW

GARDNER - DENVER

Gardner-Denver Company, Quincy, Illinois

In Canada: Gardner-Denver Company (Canada), Ltd., 14 Curity Ave., Toronto 16, Ontario

This New Catalog Covers Complete New Line of MARMAN Industrial Clamps, Couplings, Joints

New 44 page Catalog 803 covers Marman's greatly expanded line of industrial clamps, couplings and joints designed to solve the problems of fastening and joining fluid lines, containers, tanks, separators and similar units.

Presented specifically for design engineers is detailed product, performance and application information about Marman V-Band Couplings, FLEXMASTER Pipe Couplings in a wide range of configurations, all metal CONOSEAL Joints for leakproof pipe and tube connections under extreme pressures and temperatures, and other products. These products reduce manufacturing costs, improve product appearance and performance, speed assembly and simplify maintenance.

More than 20 years of experience in producing quality products for the aircraft industry plus extensive market research have contributed to the development of Marman industrial products. They have been designed for economy without sacrificing quality. For complete information send for Catalog 803.

NEW!
Low-cost hose clamp for wide diameter adjustment. Ideal for OEM and replacement.

FLEXMASTER and CONOSEAL are Aeroquip Trademarks.

Aeroquip
MARMAN DIVISION
11214 EXPOSITION BLVD., LOS ANGELES, CALIFORNIA
IN CANADA: AEROQUIP (CANADA) LTD., TORONTO 19, ONTARIO
Marman Products are Covered by U.S. and Foreign Patents and Other Patents Pending

Aeroquip Corporation, Marman Division MD-12
11214 Exposition Blvd., Los Angeles 64, Calif.

Please send me a copy of Catalog 803.

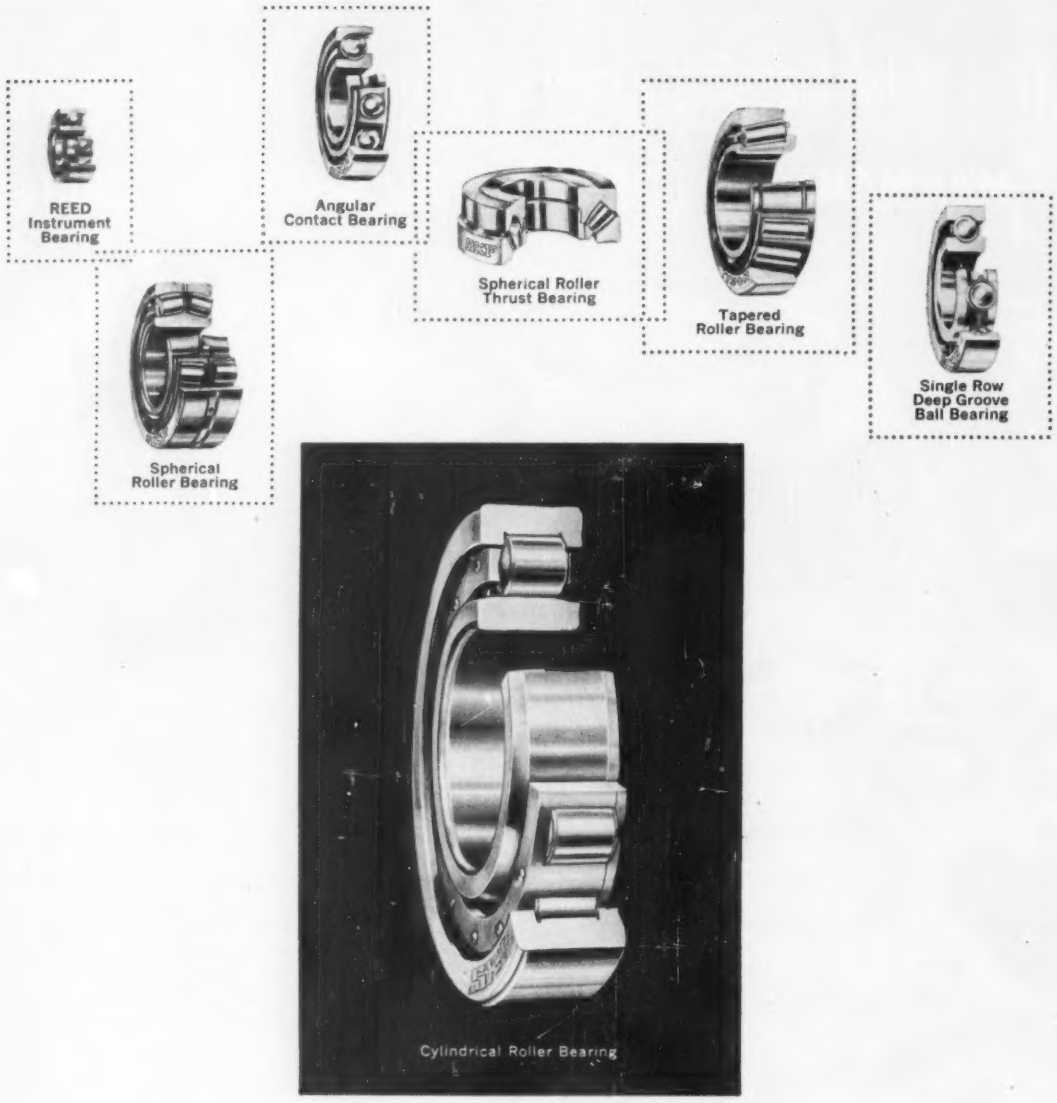
Name_____

Title_____

Company_____

Address_____

City_____ Zone_____ State_____

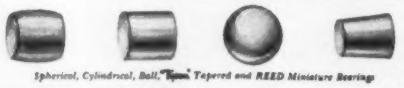


What's a "special size" in production bearings?

SKF makes so many standard sizes, there's practically no such thing as a "special size" of bearing. They range from tiny instrument bearings right up to four-row tapered roller bearings—and account for almost every possible bore size in-between.

Take SKF's standard cylindrical roller bearing, for example. It's promptly available in 154 sizes of single- and double-row types —for shaft diameters ranging from 1" to 9.5". Every size, in both types, offers high radial capacity in relation to its size and operates at highest speeds because of its very low friction.

So, before you specify a "special size" bearing, call the nearest SKF sales office first. The odds are better than 1,000 to 1 that there's already a standard SKF bearing of exactly the size you need. 6007



Spherical, Cylindrical, Ball, "Conrad" Tapered and REED Miniature Bearings

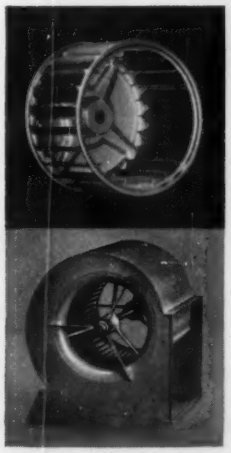
EVERY TYPE—EVERY USE

SKF

SKF INDUSTRIES, INC., PHILADELPHIA 32, PA.

Circle 447 on Page 19

EASTERN AIR DEVICES CARLIN COMPANY GILBERT & BARKER MFG. CO. STERLAIRCO DUNHAM-BUSH INC. INTERNATIONAL BUSINESS MACHINES CORPORATION DIEHL MANUFACTURING COMPANY AMERICAN-STANDARD CORP. WELBILT CORPORATION MUELLER CLIMATROL DIVISION WORTHINGTON CORPORATION McLEAN ENGINEERING LABORATORIES YORK DIVISION BORG WARNER CORP. KRAMER TRENTON COMPANY PHILCO CORP. JOHN J. NESBITT, INC. GENERAL ELECTRIC COMPANY POWER VENT DIVISION PROGRESS MANUFACTURING CO. FASCO INDUSTRIES CARRIER AIR CONDITIONING COMPANY REMINGTON CORPORATION ELECTROMODE CORPORATION PARAGON-REVOLUTE DIVISION OF CHARLES BRUNING COMPANY, INC. EATON MANUFACTURING COMPANY BUCKEYE DIVISION OF MARDIGIAN CORPORATION CHROMALOX R. W. BECKETT CORP. IRON FIREMAN MANUFACTURING COMPANY PERFECTION DIVISION HUPP CORPORATION TAPPAN COMPANY STUDEBAKER-PACKARD CORPORATION ARKLA AIR CONDITIONING COMPANY WHIRLPOOL CORPORATION BRYANT MANUFACTURING CO. BENDIX-WESTINGHOUSE CORPORATION McCRAY REFRIGERATOR COMPANY JENN AIR PRODUCTS, INC. MARLO COIL COMPANY INTERNATIONAL OIL BURNER CO. SIEGLER HEATER COMPANY KISCO COMPANY, INC. BOEING AIRPLANE COMPANY THE COLEMAN CO., INC. NUWAY CORPORATION McQUAY, INC. E. L. SCHOFIELD, INC. COLLINS RADIO CORPORATION YORK DIVISION BORG WARNER CORPORATION EUREKA-WILLIAMS CORPORATION AMANA REFRIGERATION, INC. MIDWEST MANUFACTURING DIVISION ADMIRAL CORPORATION LENNOX INDUSTRIES INC. EMERSON-PRYNE COMPANY TRADE-WIND MOTORFANS INC. RECOLD CORPORATION DAY & NIGHT MFG. CO. THE PAYNE COMPANY FRASER & JOHNSTON COMPANY HOLLY GENERAL COMPANY TUCK-AIRE FURNACE COMPANY INTERNATIONAL METAL COMPANY WRIGHT MANUFACTURING COMPANY FRIEDRICH REFRIGERATORS INC. THE MATHES COMPANY VENT-A-HOOD COMPANY FOLSOM COMPANY LARKIN COILS, INC. HEIL-QUAKER COMPANY GENERAL ELECTRIC CO. THE MARLEY COMPANY FORD MOTOR COMPANY McCORD CORPORATION PONTIAC MOTOR DIVISION GENERAL MOTORS CORPORATION CHRYSLER CORPORATION AIRTEMP DIVISION CHRYSLER CORPORATION NUWAY, CORP. MIAMI CABINET DIVISION PHILIP CARY COMPANY THE WILLIAMSON COMPANY COPELAND REFRIGERATION COMPANY WHIRLPOOL CORPORATION AMERICAN MOTORS CORPORATION AUTOMATIC BURNER CORPORATION MODINE MANUFACTURING COMPANY MASTER VIBRATOR COMPANY WORTHINGTON CORPORATION YOUNG RADIATOR COMPANY MOTOR WHEEL CORPORATION REDMOND COMPANY INC. UNIVERSAL ELECTRIC COMPANY VENTROLA MFG. COMPANY COOLERATOR DIVISION McGRAW EDISON COMPANY GIBSON REFRIGERATOR COMPANY JANITROL HEATING & AIR CONDITIONING DIVISION MIDLAND-ROSS CORPORATION NORMAN PRODUCTS COMPANY U. S. AIR CONDITIONING WESTINGHOUSE ELECTRIC CORP. EBCO MANUFACTURING COMPANY NEW YORK BLOWER COMPANY PREWAY, INC. RHEEM MANUFACTURING COMPANY JENN AIR PRODUCTS, INC. KISCO COMPANY CUSTOM-AIRE PRODUCTS DIVISION MINNESOTA MINING & MANUFACTURING COMPANY PURITRON CORPORATION



A CUSTOMER LIST IS OUR BEST ADVERTISEMENT

We design, develop, produce and test — fans, blowers and specialty air moving units — for U.S. industry.

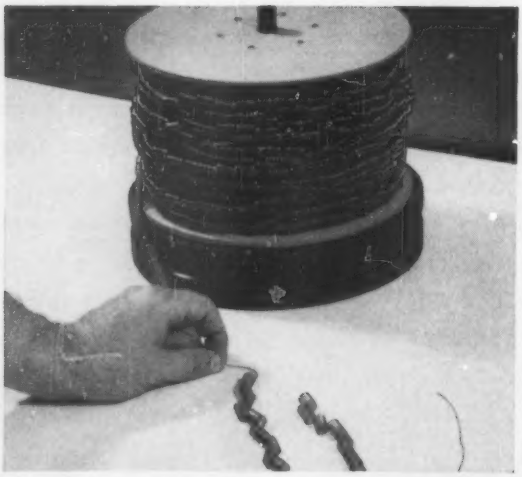
A distinguished customer list is and always will be our best advertisement!

THE TORRINGTON MANUFACTURING COMPANY

AIR MOVING DIVISIONS • TORRINGTON, CONNECTICUT • VAN NUYS, CALIFORNIA • ROCHESTER, INDIANA • OAKVILLE, ONTARIO

Circle 448 on Page 19

Reduce your assembled costs with new Spring-Flow® packaging



...more efficient handling, storing, sorting, orienting, feeding, placing of springs for installation

To production planners, Spring-Flow packaging opens up a world of possibilities for assembling A.S.C.-made springs, small stampings, and wire forms into your products easier and faster. It solves many problems caused by intricate shapes, tangling, loss by spoilage; maintains critical tolerances, uniform quality; simplifies inventory control and storage.

To learn how Spring-Flow may solve your problem, contact the nearest A.S.C. Division, or write for Spring-Flow booklet giving additional information.

8004

Associated Spring Corporation

General Offices: Bristol, Connecticut

Wallace Barnes Division, Bristol, Conn. and Syracuse, N. Y.
F. N. Manross and Sons Division, Bristol, Conn.
Dunbar Brothers Division, Bristol, Conn.
Wallace Barnes Steel Division, Bristol, Conn.
Raymond Manufacturing Division, Corry, Penna.
Ohio Division, Dayton, Ohio
Cleveland Sales Office, Cleveland, Ohio
Chicago Sales Office, Chicago, Ill.
B-G-R Division, Plymouth and Ann Arbor, Mich.
Gibson Division, Mattoon, Ill.
Milwaukee Division, Milwaukee, Wis.
Seaboard Pacific Division, Gardena, Calif.

Canadian Subsidiary: Wallace Barnes Co., Ltd., Hamilton, Ont. and Montreal, Que. Puerto Rican Subsidiary: Associated Spring of Puerto Rico, Inc., Carolina, P.R.

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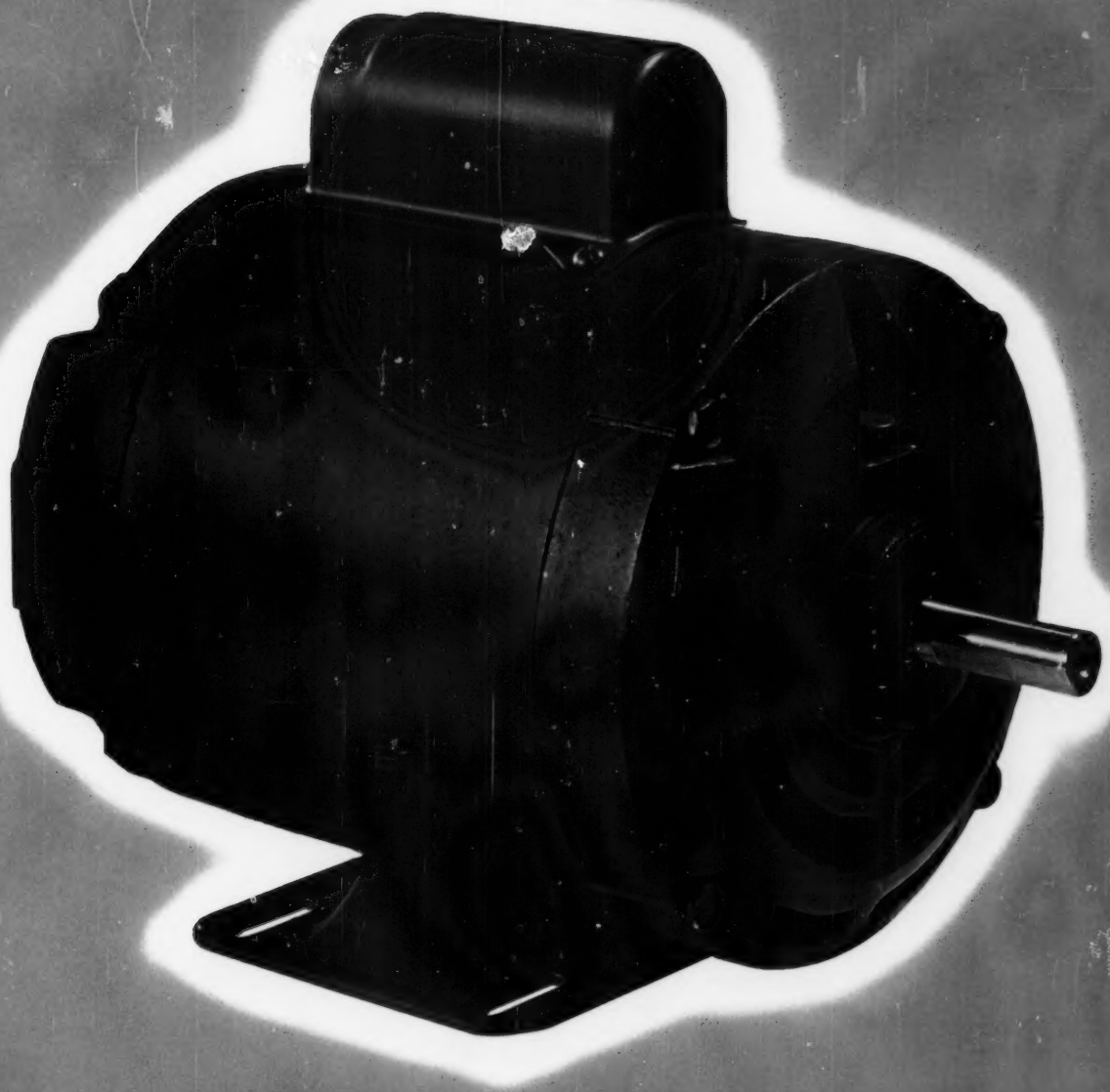


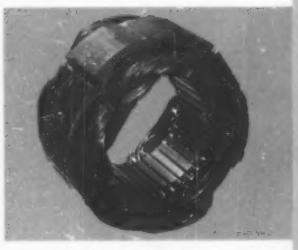
A NEW Duty Master FHP.

for heavy-duty industrial use

RELIANCE ELECTRIC AND ENGINEERING COMPANY

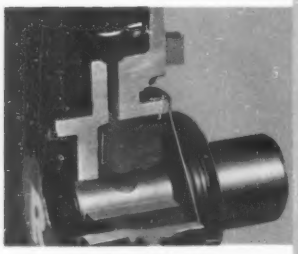
MASTER ELECTRIC COMPANY DIVISION

A NEW Duty Master FHP.

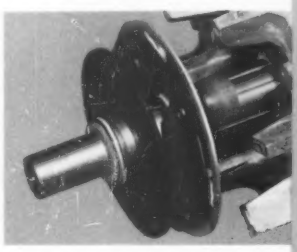


PROTECTED STATOR

TERMINAL BOARD



SLEEVE BEARING



CENTRIFUGAL CUT-OUT

TOUGH...COMPACT...COOL!

A motor that combines new, most-wanted features at no extra cost

Duty Master:

This motor is tough all over . . . deliberately designed for heavy industrial duty. Frame is rolled from steel—end shields cast from an aluminum alloy specifically selected for strength. Ball bearings are double-shielded, with lubricant packed into the bearing for life. Sleeve bearings are steel-backed and babbitt-lined for low friction and long wear. "Permawick" oil retaining material provides maximum lubrication to these bearings. Rotor is pressure-cast from high purity, low-resistance aluminum. Varnish impregnated stator resists moisture . . . and adds strength to windings.

Duty Master:

More power per pound . . . simple installation, 33% lighter than other preceding motor designs. Good design and materials make the difference. Makers of motor-driven products save on shipping and handling costs. Duty Master's light weight and small size make possible lighter, less complex mounting on equipment. Terminal board provides easy power connection in the front end shield. Cover plate quickly removable. Motor rotation easily reversed by interchanging slip-on connections.

Duty Master:

Up to 10% cooler than other comparably rated motors . . . yet gives you maximum protection. High load capacity results from new, effective ventilation of critical heat sources. Laminations, coils and rotor are literally rinsed with cooling air through new end shield design. In totally-enclosed, non-ventilated motors, the fan, cast integrally with rotor, circulates the air within the motor at a rate appropriate to efficient transfer of heat to motor frame and end shield. And load carrying capacity of the totally-enclosed fan-cooled motor is increased by a fan and shroud directing air over the frame and end shield.

Duty Master:

Quiet . . . Smooth . . . Positive. Resilient mounting composed of metal-rimmed, rubber-cushioning rings that encircle the bearing hubs on each end and support the motor. Motor can be mounted in any position. Single phase starter winding circuit automatically opens at 80% of full load speed. Action is quiet and positive.

Available now in 48 and 56 frame sizes, from conveniently located stocks. Duty Master FHP. is made in ⅛, ⅙, ¼, ⅓, ½ and ¾ hp. capacitor-start, split-phase and polyphase for 48 and 56 frames; repulsion-start induction-run in 56 frame. Your Reliance Sales Engineer or Distributor has all the facts at his finger tips. Call him or write for Bulletin B-2514. It will be sent to you promptly. B-1615

PRINTED IN U.S.A.

Product of the combined resources of Reliance Electric and Engineering Company and its Master and Reeves Divisions

RELIANCE ELECTRIC AND ENGINEERING CO.

CLEVELAND 17, OHIO

Canadian Division: Toronto, Ontario

Sales Offices and Distributors in principal cities

How Electric Home Heat Finally Became a Reality

The extraordinary versatility of Nickel that today brings you electric home heat could tomorrow bring a solution to a metal problem in your own business

Ever have a metal problem you couldn't find the answer to . . . and then discover that the solution was there all the time?

The people in the electric home heating industry needed a resistance wire that had special properties: strength and durability for long-term service – resistance to oxidation and extreme heat – good electrical resistance properties for efficient and economical operation.

They experimented – tested – then found the solution right in their own plants. For years Nickel alloy resistance wire heating elements had made dependable performance a reality in electric ranges, toasters, dishwashers, irons–had in fact introduced a new concept of quality in modern appliances.

This resistance wire – made of a special alloy with a Nickel base – will hold up under years of off-and-on heating and cooling. Will resist heat and corrosion to give the desired long service and trouble-free performance.

Now, Nickel is making electric home heat a practical reality. This winter, for example, nearly one million American homes will be heated electrically. Industry, too, is finding electric heat eminently suitable for plants, stores, office buildings – all types of commercial structures.

Your metal problem. Whether the challenge is one of stress, fatigue, corrosion or temperature extremes, Nickel and its alloys have a durability that's hard to beat. Next time *you* have a metal problem, think first of Nickel. And remember that Inco will be glad to supply any technical data you may need. Just ask us.

THE INTERNATIONAL NICKEL COMPANY, INC.
67 Wall Street INCO New York 5, N. Y.

Dependable appliances use Nickel. Electric ranges, dishwashers, toasters, percolators, irons . . . all rely on Nickel alloy resistance wire heating elements for long service life.

This symbol on a new home is your assurance of the ultimate in modern electric living. Look for it when you buy.

FOR MORE INFORMATION ABOUT ELECTRIC HOME HEATING—see your local Electric Power Supplier.

INCO NICKEL

NICKEL MAKES ALLOYS PERFORM BETTER LONGER

←Circle 450 on Page 19

How to design SALES

Why THE CONVEYOR CO.

ENGINEERING ADVANTAGES . . .

"We specified International equipment because of its excellent reputation and ready acceptance by our customers."—W. E. SAXE, President and Chief Engineer, The Conveyor Co., Los Angeles, Calif.

Here's another successful manufacturer who has a strong preference for International Power: "During the early design and testing stages we had the help of International's engineering staff for installation problems or proper application of power," says Mr. Saxe. "Our latest model features a compact, space-saving IH Model UC-60 engine mounted in the rear to power the sweeper mechanism. This is a simple installation, easy to service and repair."

International's wide range of power sizes, with features for extreme adaptability in every size, presents a choice to match most power requirements. A conscientious engineer considers parts and service coverage, ease of maintenance, and reputation of the manufacturer as well as engineering advantages. With International, you can design sales power *and* superior engineering into your product.

SALES POINTS . . .

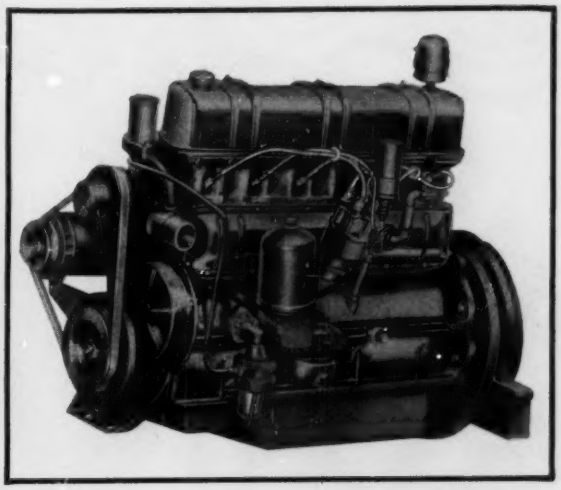
"The complete acceptance of International engines by our biggest users is a wonderful sales asset."—W. T. LARSEN, Sales Manager, The Conveyor Co.

Men who sell the Mobil Sweeper line are convinced of the profit-building, sales-clinching advantages of International engines. Here's how Mr. Larsen puts it: "We are able to show sanitation departments and government agencies many examples of years of trouble-free performance and economical operation of IH engines on Mobil Sweepers. This acceptance is world-wide. Our customers in Iran, South Africa, Japan —anywhere in the free world—know that engine service help is only a few hours away!"

Smart salesmen know that most customers back up an engine choice with years of experience. And years of experience, as reported by users from coast to coast, prove the value of International Power in heavy-duty equipment.

POWER into Your Products

specifies INTERNATIONAL POWER...



International UB-264 gasoline engine delivers 111 hp @ 2,800 rpm, provides perfect power for the Mobil Sweeper shown at left. There are 35 carbureted and diesel engines in the International line—16.8 to 385 max. hp.

CUSTOMER ACCEPTANCE...

"Our city equipment must be efficient, safe, dependable and long-lasting. IH-powered Mobil Sweepers meet these requirements."—R. G. BARHITE, Director of Public Works, City of Downey, Calif.

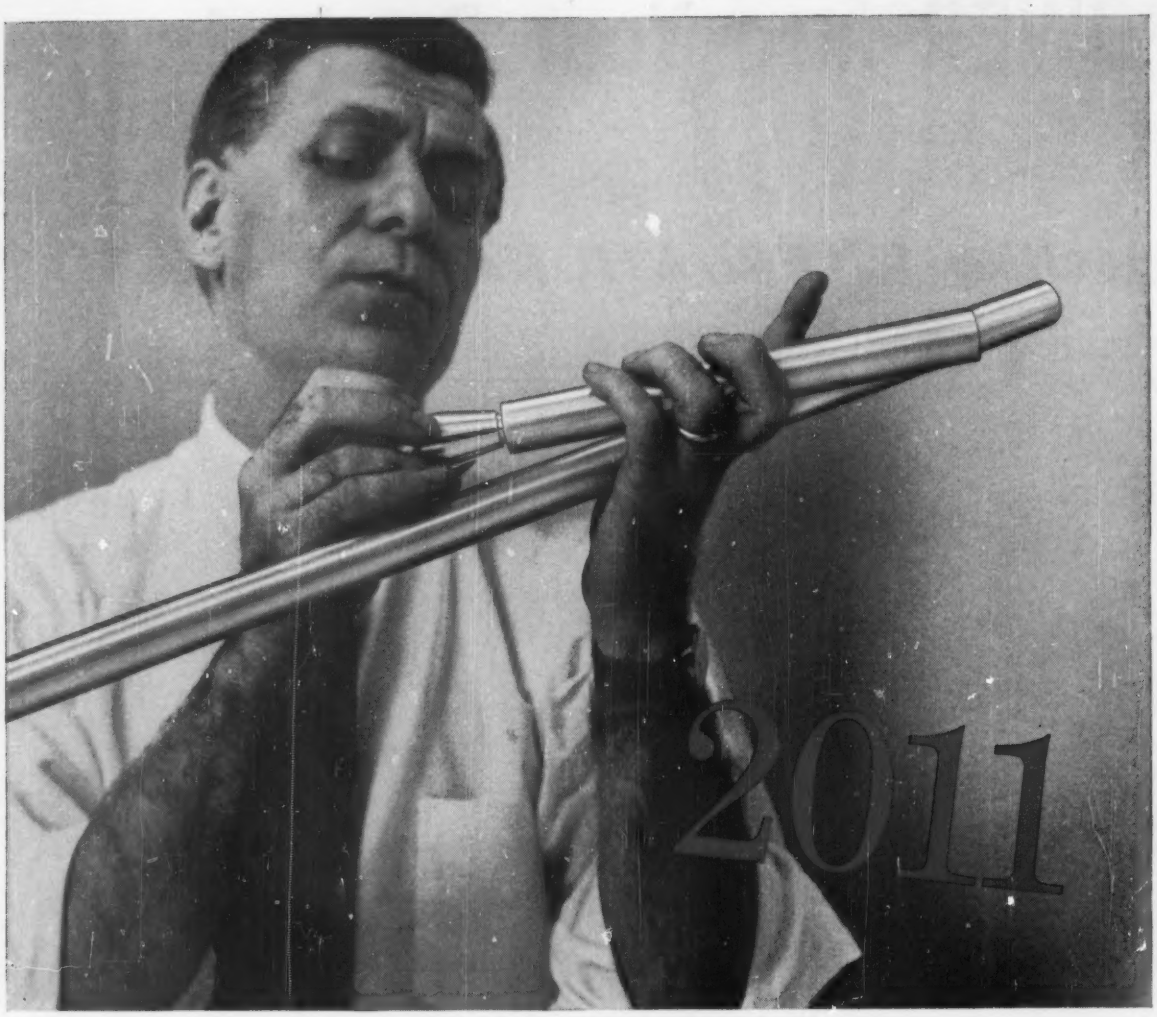
"Our first Mobil Sweeper proved itself in 34,000 sweeping miles, as have other Mobil Sweepers in neighboring towns," reports Mr. Barhite, shown at right with Street Superintendent Mel Harldson. "Our new model, also with International power, is doing an excellent job!"

International's three-way advantage of wide power selection, complete parts and service coverage, and long, trouble-free service life creates a product preference that today's sales-conscious engineer demands. Find out today how sales power can be built into your products. Call or write to International Harvester Co., Engine Sales Dept., Construction Equipment Division, Melrose Park, Ill.

INTERNATIONAL®
IH ENGINES

International Harvester Co.,
180 North Michigan Ave., Chicago 1, Ill.
A COMPLETE POWER PACKAGE

Circle 451 on Page 19



"ALCOA ALUMINUM SCREW MACHINE STOCK ALLOY 2011 CUTS YOUR UNIT COST!"

Precision-made, high-volume screw machine parts cost less in aluminum

Final cost of your machined component . . . material cost plus production cost . . . is *lower* with Alcoa Alloy 2011-T3. That's because this faster machining alloy cuts production time . . . machines easier . . . can be held to close tolerances . . . gives a bright, clean finish. And Alcoa® Aluminum 2011-T3 gives you three times as many parts per pound as other, heavier metals, for still more savings. By using Alcoa Aluminum 2011-T3 Screw Machine Stock you get all the inherent advantages of automatic screw machine products.

Be sure to ask your Alcoa distributor or Alcoa sales office for your free *Alcoa Conversion Calculator*. It makes cost conversions from brass to aluminum quick, easy, finger-tip operations. Also get your free *Alcoa Screw Machine Stock Estimating and Operating Data Book*, the most comprehensive book of its kind in the screw machine field . . . packed with easy-to-find technical data.

You'll want information, too, on other Alcoa screw machine alloys: 2017-T4 or -T451 for strength at low cost, 2024-T4 or -T351 for strength with high production, and 6061-T6 or -T651 for superior finishes, excellent joining characteristics and extra corrosion resistance. Aluminum Company of America, 840-M Alcoa Building, Pittsburgh 19, Pa.

ADDITIONAL BONUSES YOU GET WITH EVERY ALCOA ALLOY:

1. Wide range of stock sizes for important price advantages.
2. Guaranteed market for up to 60 per cent of your Alcoa Aluminum turnings and borings.
3. Extensive mill and distributor inventories to meet all requirements.
4. Chamfered ends at no extra cost.
5. Specific 12-ft lengths at no extra cost (for rounds up to 2¾ in.; hexagons up to 2 in.).

ALCOA ALUMINUM

SCREW MACHINE STOCK

Circle 452 on Page 19

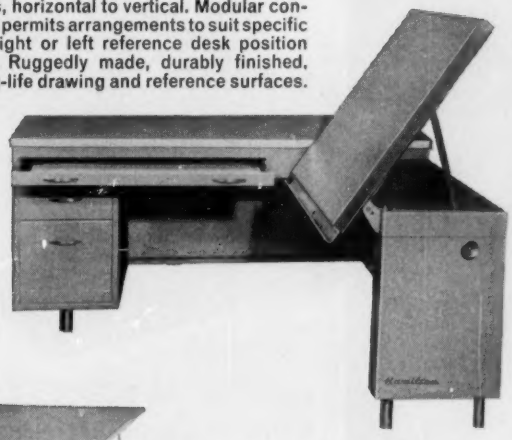
(What's wrong with this picture?)

Is your materials-handling equipment years ahead of your engineering-design equipment?

Materials-handling techniques have made great strides during the past decade—and efficient handling *is* basic to productivity. But *drafting* equipment, too, needs to stay with the times. Are your professional engineer-draftsmen *really* equipped to realize their full potential?

Your draftsmen, your productivity, deserve new Hamilton space-and-time-saving equipment—from Keuffel & Esser Co.

Hamilton L-Contour Table
Sturdy, counterbalanced, drawing surface travels full 20"—permitting frequent position change, greatly reducing fatigue—quickly adjusted to individual requirements for each individual job. Board completely stable in all positions, horizontal to vertical. Modular construction permits arrangements to suit specific needs—right or left reference desk position optional. Ruggedly made, durably finished, with long-life drawing and reference surfaces.



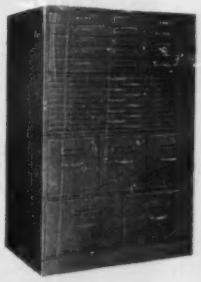
Hamilton CL 100 Series
Side crossrails are eliminated in this entirely new, canted-leg table—yet full stability is achieved. Ample drawer space for reference, tools, and catalogs—many other fine features including Strata-Core board, with green linoleum surface—that tilts 0° to 40°. Beautifully styled Sahara-Tan finish.

In practically all plants, the production cycle *begins* at the drafting board, then is controlled, checked, and qualified by this highly professional function—right up to, and sometimes through, product delivery. Your drafting personnel bring your basic product concepts, product improvements, and plant operating procedures *to life*.

Time and space are raw materials—Hamilton makes the most of them. This drafting equipment keeps working for you—because it is manufactured to rigid specifications, made of highest quality components—and, hour after hour, delivers greater comfort and less fatigue. Because drafting equipment is used by *people*—it must have the flexibility and individuality of use and dimension to fit each person and each job on the board—each individual drafting department problem.

Become familiar with the *entire* Hamilton line. We are at your service, through our experienced planning engineers, to help determine the most productive arrangements for your particular needs.

Hamilton Plan Files
Every tracing becomes a "top sheet"—each instantly accessible—when filed in the Hamilton ten-drawer unit. Individual sections of various types for various filing functions can be assembled in a number of arrangements—and stacked safely to any practical height. Tracing lifting mechanism in each of the ten shallow drawers, for filing of drawings—making each sheet instantly and individually accessible. Exceptionally rugged and durable.



K+E

KEUFFEL & ESSER CO.

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DRAFTING, REPRODUCTION, SURVEYING EQUIPMENT & MATERIALS • SLIDE RULES
MEASURING TAPES • OPTICAL AND METROLOGICAL SYSTEMS AND COMPONENTS

Circle 453 on Page 19

KEUFFEL & ESSER CO., Dept. M-11, Hoboken, N. J.

Please send me your catalogue on Hamilton Drafting Room Equipment.

NAME_____

TITLE_____

COMPANY_____

ADDRESS_____

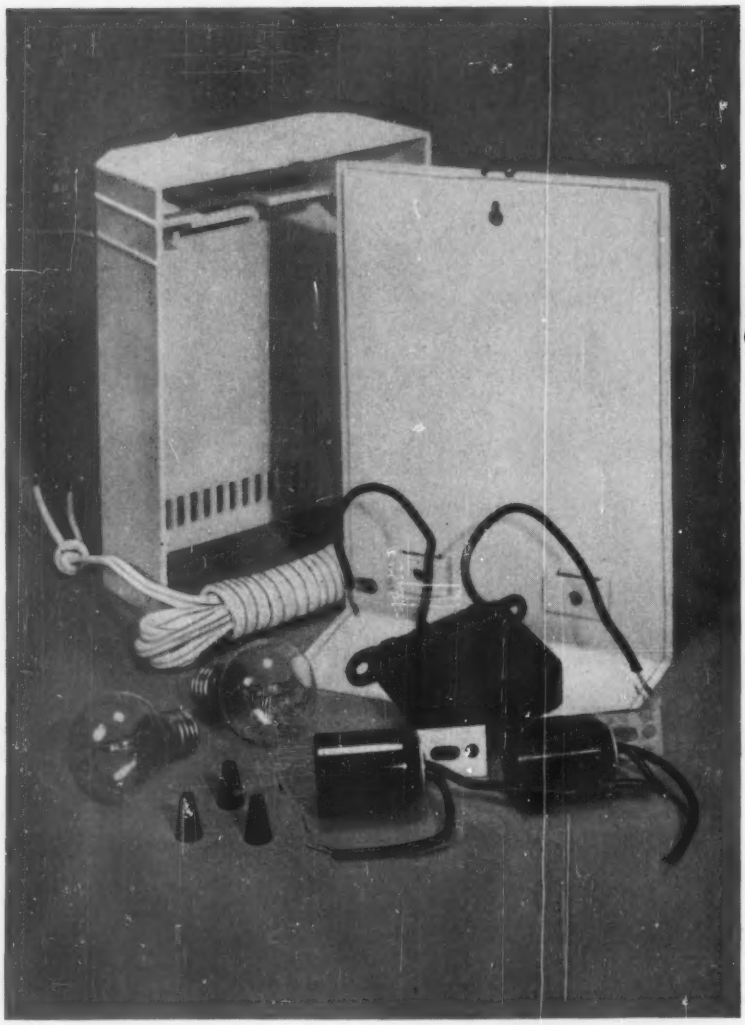
IF YOU'RE READY FOR CUSTOM PARTS

It pays to get complete QC* service by Sylvania

Sylvania helps you with completely objective recommendations for your parts. From long experience in metals, plastics, welds and assemblies Sylvania can take fullest advantage of a wide range of equipment.

Expert design assistance is available and can often improve the quality of your part and, more important, can often help lower the cost of production.

Outstanding quality parts come from the most modern equipment available plus long experience in tooling. In addition, Sylvania practices preventive maintenance for dies and equipment to assure precise uniformity and uninterrupted production.



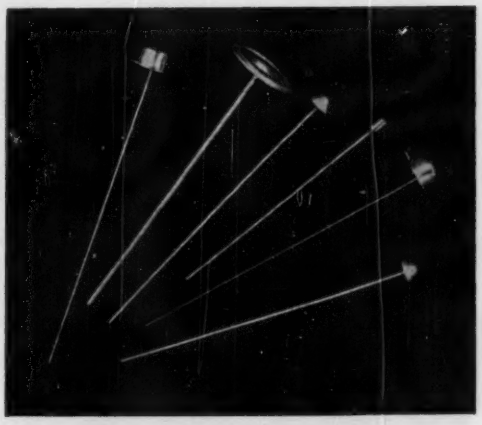
CUSTOM ASSEMBLED

Many of our customers have found Sylvania can often assemble and package a product —at lower cost than they themselves—no matter who *makes* the parts. Subassembly work can also provide customers with additional and unexpected savings.

Result: If your product is small, the parts predominantly plastic and metal, and the quantities 50,000 or more, it pays you to have Sylvania trained specialists assemble it.

FORMED FROM METAL

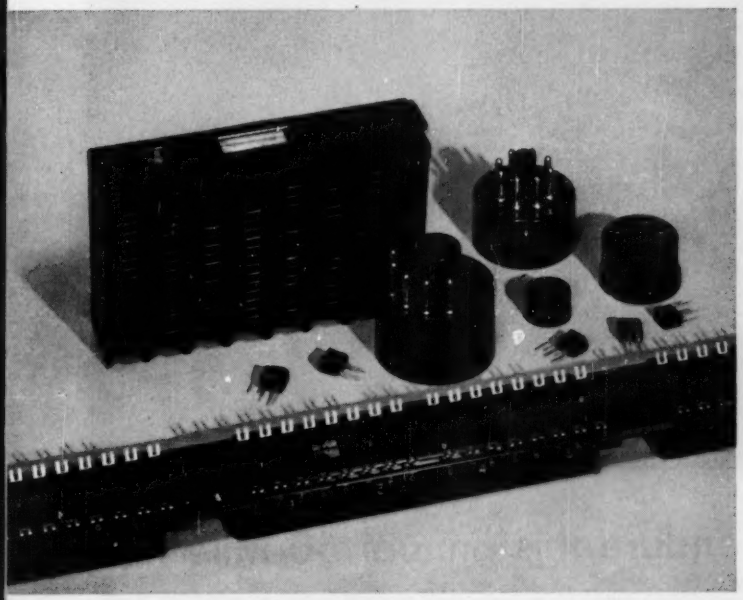
Sylvania maintains complete custom metal stamping facilities and can produce millions of precision-made parts each day from most all types of metal. These parts are available in the desired high-production quantities—to the most exacting specifications—at low cost to you. Sylvania can produce deep-draw eyelet parts, shells, cups and ferrules. Our batteries of multi-slide equipment can produce more than 2 million parts daily. Vertical presses can meet daily production needs of 2 million parts. And special, Sylvania-developed machines can turn out great quantities of small wire and ribbon forms as well as wire cuts and leads.



CUSTOM WELDED

It makes no difference if your part is standard-sized, miniature or subminiature. Welded assembly is a Sylvania specialty. To help you meet your custom assembly needs, Sylvania has developed new high-speed, high-volume welding techniques, advanced welding equipment, automatic and semiautomatic, and a corps of trained specialists.

Results: Sylvania welded assemblies assure high-quality electrical and mechanical contact, mirror-image uniformity and low cost.



MOLDED FROM PLASTICS

Sylvania offers quick, efficient production of plastic parts—and at low piece prices in production quantities. Reason? Sylvania operates one of the most complete lines of modern automatic molding equipment in the world for compression, injection and transfer molding. Our bank of rotary presses can produce more than a million parts a day, is ideally suited to phenolics and urea, and assures minimum cost for simply designed plastic parts.

*QC MEANS QUALITY CONTROL!

Sylvania maintains a complete quality control department to assure that parts are made to your exact specifications. This control works for you throughout the manufacturing cycle. It's just one more way you benefit when you have Sylvania on the job for parts.

For full details or a quote, write Sylvania Electric Products Inc., Parts Division, Warren, Pennsylvania.

SYLVANIA

Subsidiary of **GENERAL TELEPHONE & ELECTRONICS**

Circle 454 on Page 19

Only sheets of steel can endure this annual 50-mile hike

To keep a 100-by-150-foot lawn in trim a power mower churns and chatters more than 50 miles in a single season. A mower needs plenty of strength to stand up under all the hard knocks and vibration!

That's why so many lawnmower parts—handles, housings, decks—are formed from sturdy steel sheets. No cracking, no buckling, no twisting or working loose when parts are made of durable sheets of steel.

So whether your product is a mower or a motor vehicle, you're on solid ground when you design and work with sheet steel. Bethlehem can furnish the sheets you need for the job, in a wide variety of gages, tempers, and surface finishes. And our engineers will be glad to pitch in on your technical problems.

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.
Export Sales: Bethlehem Steel Export Corporation

Steel *for Strength . . . Economy . . . Versatility*

BETHLEHEM STEEL

BETHLEHEM STEEL

Circle 455 on Page 19

interchangeable with all standard JIC cylinders

With the introduction of the ALL NEW T-J Squair Head, Tomkins-Johnson now offers industry the most complete design range of air and hydraulic cylinders. Presently available in bore diameters from 1½ to 8 inches, the T-J Squair Head is an interchangeable cylinder which produces maximum force and efficiency, with minimum pressures... and is also adaptable to the use of low pressure oil as the working medium. Write to The Tomkins-Johnson Co., Jackson, Michigan, for Bulletin #SQ 10-58 and complete details.

CHECK THESE 10 POINTS OF T-J SUPERIORITY

1 One Piece Piston

2 Hard Chrome Cylinder Bore and Piston Rods

3 High Tensile Steel Tie-Rods

4 Cushion Adjusting Screw, Externally Adjustable

5 New Super-Cushion for air, or Self-Aligning Master Seal for Oil (T-J Patents)

6 Solid Steel Heads and Mounting Plates Standard all Models

7 Port Design Allows Minimum Pressure Drop on Inlet or Outlet

8 "V" Type, Self-Adjusting Rod Packing

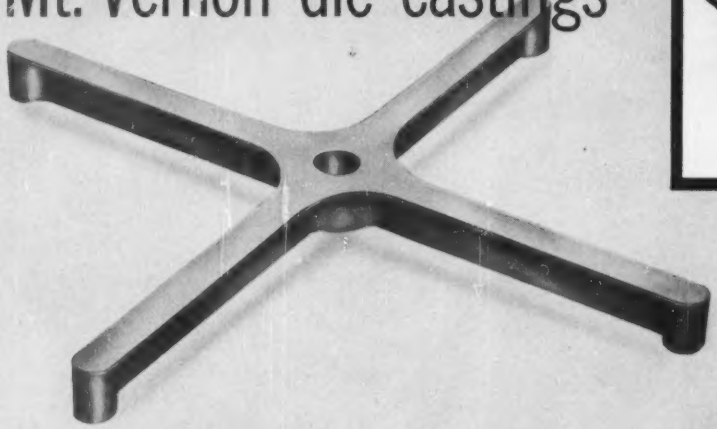
9 Piloted Packing Gland—Absolute Alignment

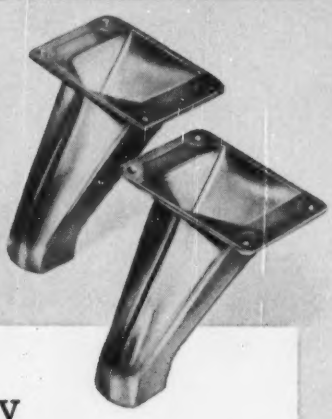
10 Piston Rod, Extra Strong—Polished and Chrome Plated for Efficiency and Protection

T-J TOMKINS-JOHNSON

Circle 456 on Page 19

Steel furniture manufacturer gets **these 5 benefits** from Mt. Vernon die castings





CASE HISTORIES FROM MT. VERNON FILES

Subject:

Art Steel Company, New York City

In a major switchover, Art Steel Company makes this handsome Steelmaster Desk with aluminum die cast legs. The companion Executive Chair stands on a die cast aluminum base. Formerly it took 8 parts to assemble each island leg of the desk... and 14 parts for the chair base. But switching to die cast parts gave Art Metal Company 5 major benefits:

1. Simpler fabrication since all castings are one-piece integral units. No more multiple section subassembly work.

2. Complete freedom in designing due to the many inherent advantages of the die casting process.

3. Corrosion of legs and bases caused by office cleaning detergents no longer a problem. Aluminum die castings stay bright and attractive.

4. Die castings are delivered polished, drilled and tapped, ready for use. Several assembly steps previously required have been eliminated.

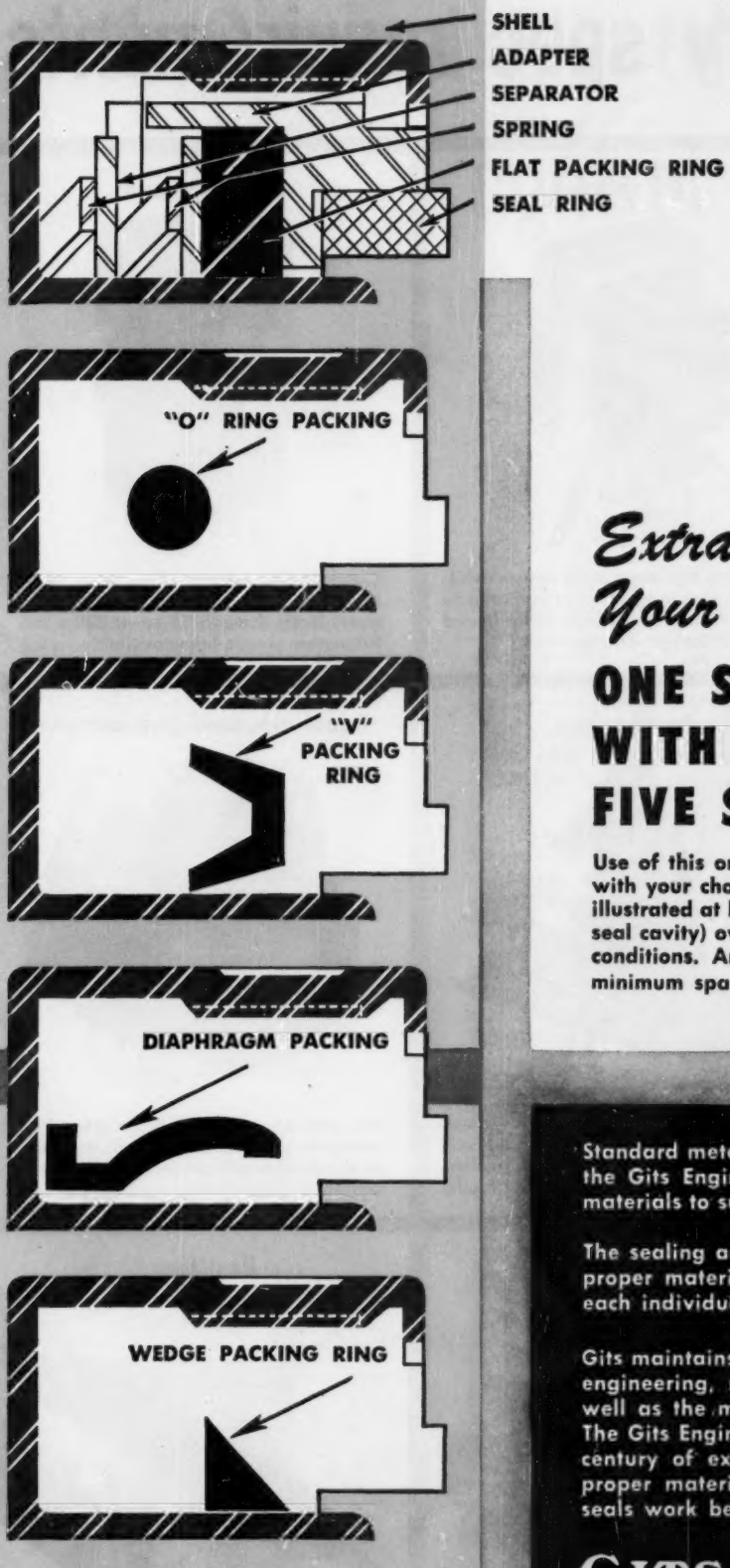
5. Because production of legs and bases has been put into Mt. Vernon, valuable production capacity at Art Steel has been freed for other requirements.

More and more, in a great variety of products, Mt. Vernon Die Castings are replacing complex sheet metal assemblies and costly, crude sand castings, bringing significant production economies to the manufacturer. All the knowledge we have gained on this subject is also available to you... free. Why not discuss your problem with us too. A call to your nearest Mt. Vernon representative will bring you action.

MT. VERNON DIE CASTING CORPORATION
STAMFORD, CONNECTICUT

SALES REPRESENTATIVES
BALTIMORE, MD.: Mr. C. M. Gordan, 919 St. Paul St.
BROOKLYN, N. Y.: Mr. Robert V. Moore, 2317 Plumb 2nd St.
CLEVELAND, OHIO: Mr. Grant Eller, 6 East 194th St.
MARIETTA, N. Y.: Mr. Burt J. Meldrum, Olanco Road
PITTSBURGH, PA.: Mr. Andrew W. Anderson, 300 Pasadena Drive So.
STAMFORD, CONN.: Mr. Anker Anderson, Cascade Road
VALLEY FORGE, PA.: Mr. G. T. McMaster, P.O. Box 115

GITS HH-TYPE SEAL SERIES



VITON "A"

All packings illustrated are available with new Viton "A" rubber compound, for highest temperature resistance and maximum resistance to aircraft and hydraulic fuels and lubricants.

Circle 458 on Page 19

GITS

Extra Flexibility For Your Seal Applications!

ONE SEAL ENVELOPE WITH CHOICE OF FIVE SEAL PACKINGS

Use of this one standard Gits HH-type seal envelope—with your choice of the five seal packing arrangements illustrated at left—permits effective sealing (in the same seal cavity) over the widest possible range of operating conditions. And all these Gits Shaft Seals meet standard minimum space requirements.

Standard metal parts are stainless steel, except when the Gits Engineering Department recommends other materials to suit specific applications.

The sealing and packing members are engineered of proper materials to suit the operating conditions of each individual application.

Gits maintains the most complete facilities for design, engineering, research, development and testing, as well as the most modern manufacturing equipment. The Gits Engineering Department, with almost half a century of experience, has the know-how to blend proper materials with outstanding design, to make seals work better for you. Send for full information.

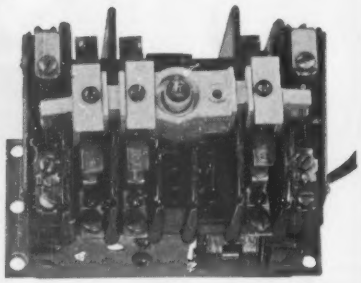
GITS BROS. MFG. CO.

1868A South Kilbourn Avenue • Chicago 23, Illinois

***NEW!** Gits engineering advancement practically eliminates hysteresis or drag. Write for full details.*

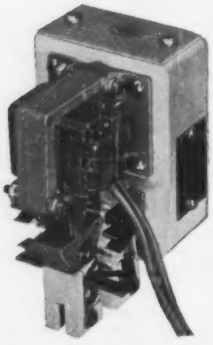
Meet military spec requirements

AC contactors



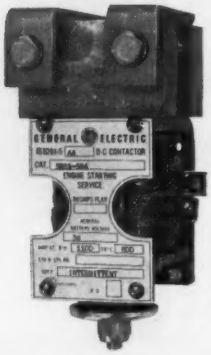
For magnetic operation on motor loads through 200 hp at 440 volts, 3-phase, 60-cycle; are available with 3 or 4½ poles.

AC relays



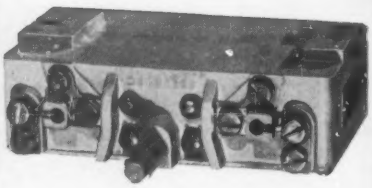
Interlocking or undervoltage relays; available with four to eight poles in ratings to 10 amps; both single-pole (above) and multi-pole contact arrangement.

DC contactors



Diesel-starting (above), time-delay, sizes 1, 2, and 3 for magnetic operation on motor loads through 25 hp at 230 v d-c. Submarine service forms available.

Thermal overload relays



Both heater- (above) and induction-type; adjustable from 90 to 110 percent of rating; resetting time 60 seconds after tripping.

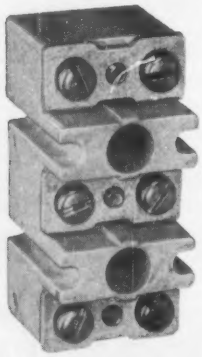
Reset relays

A remote method for resetting overload relays; consist of potted solenoid coil and a mechanical linkage on corrosion-resistant steel base with insulated leads.

Panel-mounted pushbuttons

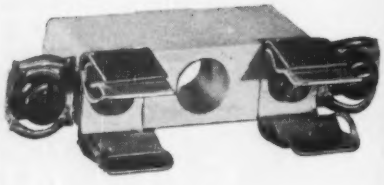
For use on a-c or d-c circuits where momentary contact is required; available in standard or oiltight forms in variety of contact arrangements.

Terminal boards



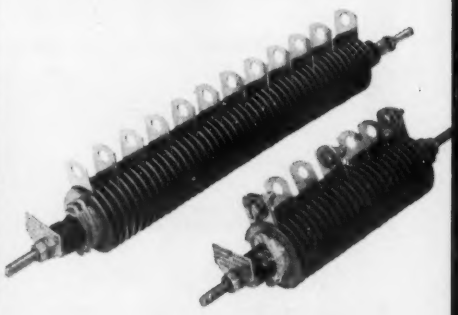
Designed for 25-, 50-, 100-, and 150-amp circuits. Termination points—either 2, 3, 5, 7, or 9—have fire-resistant base.

Fuse blocks



Rated up to 30 amps; blocks consist of a fire-resistant molded-compound base with metal terminals and fuse clips; convenient single-hole mounting.

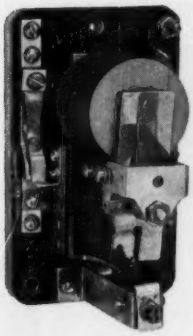
Resistors



Starting and regulating duty on motor and generator field adjustment, load banks, etc.; available in ratings from 21.5 to 42.5 amps continuous and five lengths.

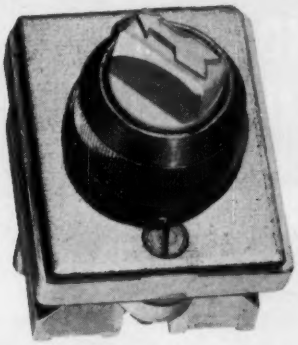
with General Electric HI-shock control components

DC relays



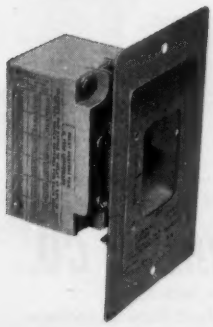
Multi-current and overcurrent relays (above) are used as interlocking or undervoltage relays, and on electronic applications requiring shock-damage design.

Panel-mounted selector switches



For use on either a-c or d-c circuits where maintained contact is required; available in three forms; can be mounted on panels up to 3/16-inch thick.

Manual starters



For single-speed, 1- or 3-phase, squirrel-cage induction motors or d-c motors. Size 0 starters are dripproof or flush-mounted; rated 3 hp 440-volt a-c maximum.

A complete line of devices designed for extreme environmental applications

- Shock
- Humidity
- Fungus
- Vibration
- Tilting
- Temperature

Whether you're designing equipment to meet exacting Navy specifications . . . or for missile hard-site applications where adverse environmental conditions are inherent . . . one or more of General Electric's HI-shock control components may well be the answer to your circuit design problems.

All General Electric HI-shock control components are designed, built, and tested to perform reliably in virtually all operating conditions including shock, humidity, fungus, vibration, tilting, and high or low temperature.

Outstanding features you get with the complete line of General Electric HI-shock control devices include: 1) all front connection for easy servicing; 2) fire-resistant compound bases, and 3) all corrosion-resistant metal parts.

CATALOG OFFERS COMPLETE DESIGN DATA

General Electric's Control Components Catalog contains dimensional outlines, electrical design data, environmental limits, MIL Spec references, and prices on all HI-shock devices. To have this valuable information at your fingertips, call your General Electric Sales Engineer today. Or, mail the coupon below. Industry Control Department, Salem, Virginia.

Progress Is Our Most Important Product

GENERAL ELECTRIC

Circle 459 on Page 19

SEND TODAY FOR FREE CATALOG

General Electric Co., Section E785-15
Schenectady 5, New York

Please send me a copy of the Navy Control Components catalog, GEA-6798, with descriptions, specifications, and pricing data on the complete line.

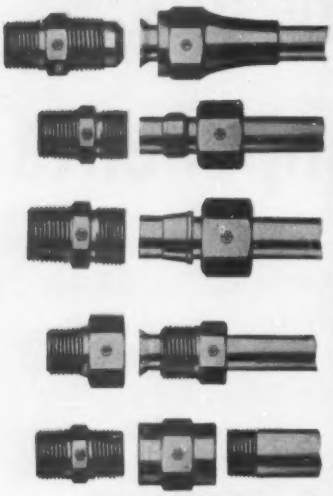
Name_____

Company_____

Address_____

City_____ State_____

brass tube fittings



S.A.E. 45° FLARE
USE with copper, brass, aluminum, steel and plastic tubing. U.L. listed; A.G.A. approved. Meets SAE Hydraulic standards and A.S.A. and A.S.M.E. codes. PRESSURE RATING: up to 3000 p.s.i. Sizes: ⅛" to ¾".

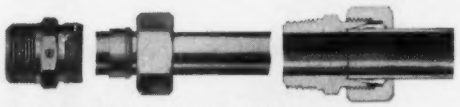
COMPRESSION
USE with copper, brass, aluminum and plastic tubing. U.L. listed; A.G.A. approved. Meets SAE Hydraulic Tube Fittings Standards and A.S.A. and A.S.M.E. codes. PRESSURE RATING: up to 2000 p.s.i. depending on O.D. of tube. Sizes: ⅛" to ¾".

SELF-ALIGN®
USE with copper, brass, aluminum and plastic tubing. No flaring, soldering, welding, or special tube preparation needed. PRESSURE RATING: up to 2000 p.s.i. Sizes: ⅛" to ¾".

INVERTED FLARE
USE with copper, brass, aluminum, steel and plastic tubing. Meets SAE Hydraulic Tube Fittings and A.S.A. and A.S.M.E. codes. PRESSURE RATING: up to 3000 p.s.i. Sizes: ⅛" to ¾".

PIPE FITTINGS
USE with brass or steel pipe. Meets specifications of SAE TPHL Fittings Committee. PRESSURE RATING: up to 5000 p.s.i. Sizes ⅛" to ¾".

forged steel fittings



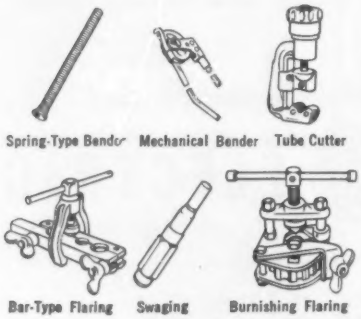
ERMETO HYDRAULIC TUBE FITTINGS
Most dependable high pressure fitting in the world . . . easiest installation. FOR FLARELESS TUBE SYSTEMS. No flaring, threading, welding or soldering. Available with carbon steel; stainless steel; cadmium plated or Weathercote finish. Standard Sizes: ⅛" through 2". Pressure Ratings: up to 10,000 p.s.i.

FLARE-TWIN HYDRAULIC TUBE FITTINGS
SAE 37° FLARE (J.I.C.) STEEL FOR FLARE TUBE SYSTEMS. No threading, welding or soldering. Two-pc. and three-pc. carbon and stainless steel with cadmium plated or Weathercote finish. Standard sizes: ⅛" through 2". Pressure Ratings: up to 10,000 p.s.i.

the WEATHERHEAD symbol is your assurance of SERVICE, QUALITY and DEPENDABILITY in all industrial hose and tube fitting needs

tube working tools

Designed to make fast, easy work of every tubing job. We offer a complete line of low cost, quality made tools for cutting, bending and flaring tubing up to ¾" in O.D.



Spring-Type Bender · Mechanical Bender · Tube Cutter

Bar-Type Flaring · Swaging · Burnishing Flaring

hose

Available in over 20 different types for any industrial application up to 10,000 p.s.i. pressures and sizes from ⅛" to 2" I.D. Five standard hoses meet most requirements.

H-9—Low Pressure

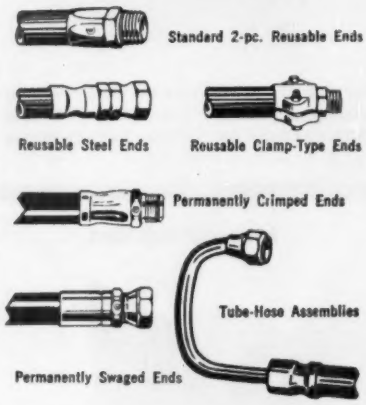
H-17—Medium Pressure

H-25—High Pressure

H-69—Medium High Pressure

H-108—Medium High Pressure

hose assemblies



Standard 2-pc. Reusable Ends

Reusable Steel Ends · Reusable Clamp-Type Ends

Permanently Crimped Ends

Tube-Hose Assemblies

Permanently Swaged Ends

FOR DETAILS
See Weatherhead catalog in Sweet's Product Design File, Plant Engineering File, the Fluid Power Directory, or write direct.

YOUR SINGLE SOURCE SUPPLIER OF ALL INDUSTRIAL HOSE AND FITTINGS NEEDS

THE WEATHERHEAD CO.
FORT WAYNE DIVISION • **Dept. MD-12**
128 West Washington Blvd. • Fort Wayne, Indiana
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if cost reduction is your problem

value analysis *dictates*

NATIONAL HTM CASTINGS

To make or buy — to cast, forge or fabricate — that is often the question.

Before you decide, look into the advantages of National HTM (pearlitic malleable) castings over other methods of forming.

Among the great advantages of National HTM castings are closer as-cast tolerances that often eliminate machining operations . . . excellent response to subsequent hardening operations, either induction or flame . . . easy machinability on your present equipment . . . high ultimate strength . . . excellent non-seizing bearing qualities . . . air or liquid quenching . . . ability to be smooth-finished.

Yes, Value Analysis often makes the use of *National HTM castings a must.* And remember National HTM castings can be precision cast by the shell mold, CO_2 or green sand methods. Production costs tumble . . . performance and salability of your product spurt — with National HTM (pearlitic malleable) castings.

AA-9816

NATIONAL MALLEABLE and STEEL CASTINGS COMPANY

Established 1868 — *Cleveland 6, Ohio*

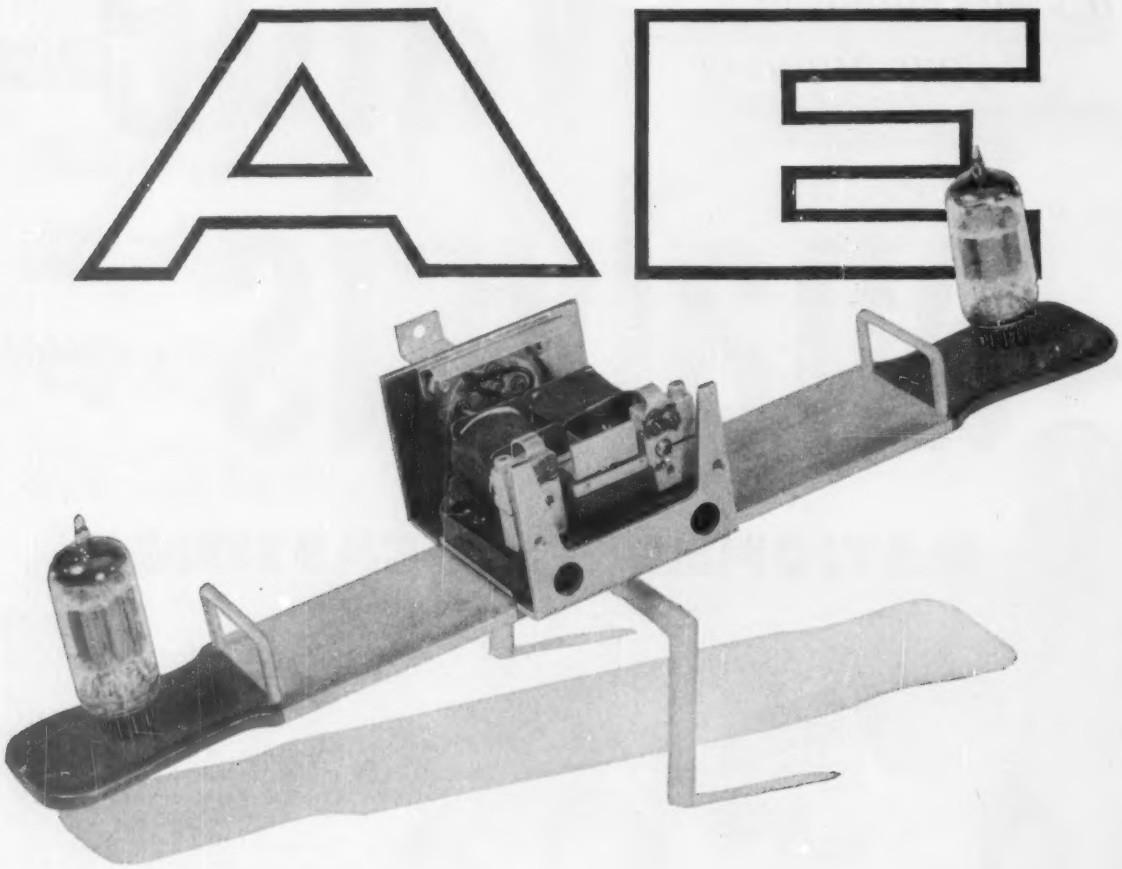
The nation's largest independent producer of malleable and pearlitic malleable

MEMBER MALLEABLE CASTINGS COUNCIL

Circle 461 on Page 19

Important Physical Properties	
Brinell	163 to 302*
Yield, psi	48,000 to 85,000*
Ultimate, psi	70,000 to 110,000*
Elongation, %	7 to 2*

*Depending upon grade



To the Engineer

looking for a fast circuit seesaw

If you're in need of something better than a flip-flop that only *partially* transfers a circuit –something with a transit time of less than a millisecond–then you'll be delighted with AE's Series PTW Polar Relay. This magnetically biased relay will transfer a circuit with the beautiful regularity of an observatory clock, and trigger on only a few mils from your available energy source.

Substantially smaller than other polar relays, the PTW's unique design virtually guarantees the high-speed switching of a single circuit *billions of times without readjustment!* Its service records to date in telegraph and teleprinter circuits and differential controls suggest that its life is practically limitless. Terminals to meet your specs.

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For full information on the PTW, ask for Circular 1821-E – *and* for answers to your control problems, write the Director, Control Equipment Sales, Automatic Electric, Northlake, Illinois.

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Circle 462 on Page 19

Circle 463 on Page 19→

"KEYSTONE WIRE made this part possible" at International Screw Company

flowability IS THE SECRET

International Screw Company, Detroit, Michigan, manufactures a special weld stud fastener for one of the 1961 automobile models. The combination large head, deep collar and weld points required unusual flowability.

This weld stud now is formed in an extreme double blow with no head or collar cracking. Keystone Cold Heading Wire fills the dies completely giving sharp, clean edges . . . long die life and trouble-free production runs. Of this, W. C. Nelson, President of International Screw says, "Keystone Wire made heading this part possible."

Here is another case where Keystone Cold Heading Wire and its flowability characteristics solved a difficult forming problem. May we suggest you, too, try Keystone Wire for difficult cold heading jobs, and for ordinary ones, too!

A Keystone Wire Specialist will gladly discuss your wire forming problems with you and make recommendations. Call him at an early date and let him show you how Keystone Flowability can help you, too.

Keystone Steel and Wire Company, Peoria, Illinois

KEYSTONE

WIRE FOR INDUSTRY

MANUFACTURED AT PEORIA, ILLINOIS, U. S. A.

DESIGN

December 22, 1960

Man in the Middle

DOES management really care whether engineers join unions? Latest findings of the Professional Engineers Conference Board for Industry point to a resounding "yes."

According to the board's report, out this month, 91 per cent of managers interviewed feel it is very important (64 per cent) or fairly important (27 per cent) for engineers to have thoroughly accepted status of professionals in their company. And 98 per cent feel that unions for engineers would hurt the profession.

On the other side, the labor unions make no secret of their plans to invade the professional fields. As one leader put it, the labor union movement must break out of its shell. Obvious target for union organization is the huge engineering profession.

With a new national administration that is openly aligned with the union leadership, and perhaps in its debt for helping swing the election, labor's odds in general have greatly improved.

What are labor's chances of a real breakthrough into the engineering profession? If he is truly a professional man, the engineer in industry must align himself with his employer's viewpoint and objectives. But the study already mentioned shows that only 35 per cent of engineers say they "investigate economic factors top management must consider." Worse than that, only 7 per cent of managers say that their engineers do this.

To put it bluntly, almost two-thirds of engineers today fail to understand one of the first principles of a truly professional relationship with a client. Management is even more pessimistic. Can you blame Mr. Reuther and his cohorts for believing they have a ripe field here?

As the man in the middle, the engineer who values professional status must think and act professionally. And this should be so obvious that management can't fail to recognize it.

Then, and only then, can management be expected to treat engineers as full-fledged professionals.

Colin Carmichael

EDITOR

How to look at

Spending for

PHILIP MARVIN
Division Manager
Research and Development
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When new products are being considered, queries about realistic engineering expenditures must travel a two-way street. Persons closest to the job—engineering managers and individual engineers—know best the cost of details. Upper management can best view expenditures in the light of long-range plans and company-wide objectives. Coordination between the two is a business necessity. Here's how each must consider the other, to the profit of the total organization.

Product Development

HOW MUCH should a company spend for product development? Companies that spend too little quickly find themselves in an unfavorable competitive position. Companies that spend too much find themselves in an unfavorable profit position.

The fact that an exact answer can't be given to the question tends to lull some into complacency. They say "Since no one can tell us how much to spend we might as well go on guessing." This attitude hasn't paved a pathway to success for a good reason: While you can't determine how much should be spent for product development with the precision one might hope for, some guide lines can be established which help in positioning product development activities.

What are the product development activities? Product development includes all of those activities that are essential to finding out what a company needs to strengthen its product portfolio and what opportunities can be exploited. Needs must be determined. Ideas for new products must be collected and evaluated. The best must be turned into technically and economically feasible products. New products must be put into the hands of satisfied customers to prove that the development can be successful on a larger scale operation. This is the scope of product development.

Any effective thinking about product development must look at product development as a process in which all of the supporting roles played by individual functions are subordinated to the over-all objective of developing new products, improved products, and products that can be produced at substantially reduced costs.

The answers to ten questions, Table 1, help to determine how much a company should spend for product development.

Basis for Effective Action

Those who are in charge of a business know more about their special needs than anyone else. Because of this, guide lines in Table 1 are all that can ever be offered. Some will make better use of these guide lines than others, and here are some of the reasons why.

First, some have learned how to develop data for decision making. In the long run, time is saved and decisions are easier to make if the necessary background information on which to base decisions is developed before decisions are made. The alternative course usually involves a greater amount of time and energy in corrective measures to repair damages resulting from hasty decisions.

Some commit themselves to decisions too soon—before they are compelled to act. These men succumb to the "strike directly at the problem" school of action. This, in theory, is good, but is rarely practical because most of the time you can't focus directly on the problem. The more successful decision makers take a more leisurely walk around the

problem area. They gather facts that they use both to focus on the problem and to feel their way toward a solution.

Second, others have gotten more mileage out of their technical resources. For example, if today's supply of scientific and engineering manpower were effectively utilized, there wouldn't be any talk of shortages.

Third, some companies make effective use of the output of their technical efforts. One of the greatest wastes of a corporation's time, money, and manpower today, shows up in new product development activities. Why? Because the corporation isn't organizationally structured to absorb and put to use new products as rapidly as they are created. On one pretext or another with which most of us are familiar, good ideas are shelved while management orients itself to the newness of the idea. When

Table 1—Ten-Question Guide for

1. What is the average expenditure for product development in our industry?

Expenditures of other companies in the same industry are a measure of the competitive effort. The level of competitive effort isn't sufficient by itself, but it does serve as a bench mark.

A survey of some 1000 companies over a four-year period makes it possible to establish levels of product development expenditures for 25 industry groups. Expenditures in the groups analyzed range between 1 and 8 per cent of annual sales.

Industries in the 1 per cent group are: Food and beverages, paper and paper products, petroleum refining, steel.

Industries in the 2 per cent groups are: Agricultural machinery, engines and turbines, fabricated metal products, mining, nonferrous metals, plastic and molded products, printing and publishing, rubber and rubber goods, clay and glass, textiles, transportation equipment.

Industries in the 3 per cent group are: Aircraft, autos, electrical machinery, miscellaneous machinery and parts.

Industries in the 4 per cent group are: Chemicals, construction machinery, office machines.

Industries in the 6 per cent group are: Instruments, pharmaceuticals.

Industries in the 8 per cent group are: Electronics.

It must be borne in mind that no two companies have identical product lines. These variations require correspondingly varied expenditures for product development. Roughly, development expenditures are inversely proportional to sales volume.

In using figures for any industry, one must be sufficiently familiar with the industry to understand the extremes that exist there, and to know how to position one's own company within the industry. Then, too, accounting practices vary from company to company.

The fact that the use of industry data calls for judgment and experience doesn't create particularly unusual problems. All decisions are based on exercise of judgment.

2. How effective are our product development efforts compared with others in our industry?

If each of five companies in a single industry had identical product lines and each was spending 4 per cent of its sales dollar for new product development, one company would probably grow in size and profit position beyond the other four.

3. What is the least amount we could spend for product development and stay in business?

Low limits for product development expenditures are established by the cost of those programs which, if eliminated, would result in a loss of competitive position within a short time. Redesign and product improvement programs may fall in this category. Such projects may have a clearly calculable pay off.

4. Can we use the end products of development programs?

In every company, upper limits are established by the ability of the company's management to effectively administer the new problems that necessarily accompany any new product. Can it raise new capital? Is additional management time available? Is manufacturing capacity available? Does the sales force know how to handle new items?

5. What are the uncertainties arising in calculating costs of individual new products undertakings?

All new product development activities involve uncertainties. When a proposed group of projects appears too heavily weighted on the speculative side, it is a good idea to inject projects having a less speculative nature to balance the mix.

The opposite situation deserves careful inspection too. If most of the projects are of a nature such that their outcome seems assured, the company isn't thinking far enough ahead. By the nature of their products, some industries move forward faster than others. In these situations, a company is forced to undertake speculative programs.

competitors can move faster, markets are lost.

Those who have scored outstanding achievement records haven't done so because the direction to be taken was indicated by a clearly blazed path and precise formulas for action. Rather, these records have been achieved by those who knew how to make use of guide lines. Management did a better over-all job of decision making. They made better use of their technical resources. They made better than average use of the various functions associated with new product development. Effectiveness of guide lines will be multiplied many times over as companies develop skill in using them.

Basic Problem Areas

The current competitive climate presents some problem areas that are of unusual significance. They create opportunities for those companies organizationally structured to capitalize on them.

First, technology is a dynamic force. It is the

Product Development Expenditures

6. To what degree have we been successful in putting new products into the hands of satisfied customers?

No new product development program is successful until a sufficient number of customers are satisfied to prove out the venture. When some parts of the process aren't being performed effectively, it is better to reduce the number of projects and to concentrate on the successful completion of these before undertaking others.

7. Does our management understand the concepts and operating fundamentals that lead to growth?

Size isn't the important factor in achieving growth goals. It is knowhow. Nor is growth a matter of company size or age. Both small and large companies have expanded and are expanding. Both well established and recently organized management teams have been successful in planning for growth.

It has been clearly established that successful product development programs are dependent upon management groups that understand the concepts and operating fundamentals that are basic to establishing the targets, time tables, and techniques that lead to growth.

8. Are we planning for our future?

Some have become so preoccupied with today's business that they have forgotten all about tomorrow's business. Even in some of the newer, currently expanding business, evidence of the symptoms of stagnation is becoming visible.

An advertisement appearing at the beginning of the 20th Century featuring the Stearn's automobile. It made an interesting claim:

> Use it until it wears out. There never will be a car materially better, for invention in this line has about reached the limit—to build anything better, with man's present knowledge, is utterly out of the question.

We don't hear much today about companies who were too sure of having all the answers. Others who were sure they *didn't* have all the answers are among the present giants on the industrial scene.

9. Have broad objectives been established by management to outline the scope of product development activities?

It is difficult to determine how much should be spent for product development if you don't know what you are trying to accomplish.

In most companies, new products are needed: a. To insure that the company will continue to operate in areas of growing business activity and profit potentials. b. To make the best possible use of the company's resources, such as raw materials, technical specialties and management talent. c. To utilize available markets adequately. d. To insure steadily increasing and stable profits. e. To contribute to the corporation's ability to accept social and humanitarian responsibilities.

A management finding that its programs don't include each and every one of these broad objectives, would find it well worth the time to re-examine its product programs.

10. Are we allergic to newness?

Most businesses get their start from a single good idea. Someone or some few have sensed the potential in the idea and started a business venture. Business after business can trace its origin to such courageous innovation. But once one has gone through this process of courageous innovation something seems to happen. The pioneer turns conservative. He rejects the very process of innovation that gave him his start.

It is equally dangerous to swing to the opposite extreme. The secret of success isn't necessarily "firstness." While most businesses can trace their start to a single good product idea it doesn't always follow that it's best to be first every time.

In any product venture a company may be an innovator, a leader, a follower, or a laggard. The important thing is to be able to choose the right category for the right reason at the right time.

Businesses that have achieved successful growth records, have put themselves in a position where they could pick and choose their way.

arch foe of established order and procedure. It creates constantly changing conditions. It creates radically new opportunities. Each must be examined in its own setting, but as opportunities to be capitalized upon by management methods tailored to new needs. Up-to-the-minute orientation, information, motivation, techniques, and skills are essential if companies are to turn new technology into profits.

Second, the management of scientists, engineers, inventors, planners, application specialists and others who turn ideas into saleable hardware, calls for special talent. The most needed ingredient is balance. Men who can sense potentials in new ideas without forgetting the needs of the present are the men needed. No new idea is worth anything to a business if its impact will be disastrously disruptive to the company's bread-and-butter resources. Yet, anything new is disturbing to a degree.

Third, investment in new product development, soundly administered, not only has been proved to pay its way but to yield dividends that can be reinvested in greatly expanded new programs. This aspect is an asset to those who had the foresight to start early programs.

Planning for the Future

Speculation seems to be a substitute for action for many. Too much talk about an age of technology seems to dull the senses of some to the need for action to cope with—not so much problems—but opportunities. Every problem presents an opportunity. Most decisions that must be made in business today fall into one of two categories: Decisions must be both operations-oriented and opportunity-oriented to cope with today's needs.

The greatest rewards are going to those who can tap and harness new technology, who can turn this new technology into profitable new products. One of the greatest barriers to this results from thinking about parts of the process of product development, rather than the total picture. There is a tendency to deal with research in the physical sciences, engineering, the measurement of consumer acceptance, prototype development, customer application, and product pioneering as if they were utterly unrelated. This results in a waste to time and money stemming from duplication of efforts and communications breakdown.

New product development operations have presented a confusing pattern. Diffuse terminology and overlapping functions have been responsible. Because of this the various activities which should have multiplied their individual effectiveness, have actually cancelled out each other's potential effectiveness.

The compartmentalizing effect of terminology, terms such as applications engineering, research and the like, has made it difficult to capture the all important totality of viewpoint and perspective essential ultimately to sound decision making.

Profits depend on the total viewpoint. To grow, the company needs to expand its resources. It needs to be able to detect and develop new knowledge, commercially feasible products and processes as well as all important profit opportunities. It needs to do this job continuously with a minimum of time lag and at the lowest possible cost in dollars and management time.

Some look upon the industrial corporation as one in which men, money, materials, machines, and management are turned into products and profits. But this is true only after ideas and information are turned into plants and programs.

The Job Ahead

Product development has the responsibility of executing functions that are essential in providing the company with products that will insure its position profitwise in the years ahead. To do this, programs must be put into motion that will:

1. Develop new knowledge and understanding of phenomena, materials, and the art that can be used by the corporation.
2. Develop technically and economically feasible products and processes that can be used by the corporation and its customers and which can be produced, distributed, installed, maintained, and serviced.
3. Define profit centers as investment opportunities for further expansion of business through development and acquisition.

To accomplish these ends quickly and effectively, all of the important functions essential to the achievement of these objectives must be adequately performed and competently co-ordinated. Functions that growth companies have found important range from business conditions and technological forecasting to new product pioneering.

To accomplish these ends effectively, primary responsibility for these functions must be brought to a common focus. Functions concerned with generating new and profitable products, along with proving that they can be transformed into profit producers and with putting them on to the market and turning them into profit producers, are uniquely interrelated.

Plans and action patterns must be co-ordinated for a fast-moving, hard-hitting attack. Effective use of ideas, total utilization of resources and sound decision-making, all depend on this co-ordination.

Levels of expenditure for product development will and must vary from company to company depending upon the degree to which product development activities are adequately co-ordinated.

Product development isn't an easy undertaking but it is an important one to business growth. Any growing and profitable business organization must concern itself not only with its present position in the market but its future. It should recognize that it must always combat competition.

On those product lines which already return a

satisfactory profit, the product development group must give adequate thought and attention to product changes that will be necessary to maintain or improve still further these profit positions.

Looking ahead, new needs and new opportunities must be anticipated. Development work must be initiated to meet these new needs.

There are those who tend to think that everything has been done. They have always been with us and will always be with us. Before the turn of the first century nearly 1900 years ago, Seneca, the philosopher, made this observation. He wrote: "There is still much to do—even if it turns out that the ancients discovered everything, the application, the perception of cause and effect, and further development of that which has been discovered by others, will always remain new." It turned out that he didn't have much to worry about.

A Plan of Action

It is time to toughen up management thinking about products for the future, to broaden the base for this thinking, to scan the horizon in depth as well as breadth, to think broadly in terms of the scope of its activities, and to hold product planning responsibile for figuring out what will pay off and when.

The guide lines designed to help determine how much should be spent for product development, tell that there are upper as well as lower limits to the effective expenditure of money in every corporation. This was the first concern in thinking about how much to spend for new product development. But shifting attention to the broader picture, there isn't any reason why corporate patterns should remain static. Too many examples prove that when this happens, others move in to capture the business. Once upper limits have been established for effective product development, a re-examination of these upper limits is in order. These upper limits were established because under existing conditions the corporation couldn't effectively operate product development programs on an increased scale. But why not change things so that the company can take advantage of additional profit opportunities?

To capture a leadership position, inefficiencies and wasted resources must be minimized. Corporations must be organizationally structured to utilize new developments and to examine each in its own setting, and to capitalize on these new ideas through management methods tailored to take advantage of these new ideas. To achieve this:

1. The horizons of management thinking must be broadened.
2. Those activities that create, guide and coordinate development programs must be given top level attention.
3. To foster future growth, management must be assured that properly disciplined minds are searching in the right directions. Technology is advancing at an alarming rate. It creates conditions calling for sweeping reappraisals of management thinking and action patterns, if management is to turn ideas into dollars at the lowest possible cost.

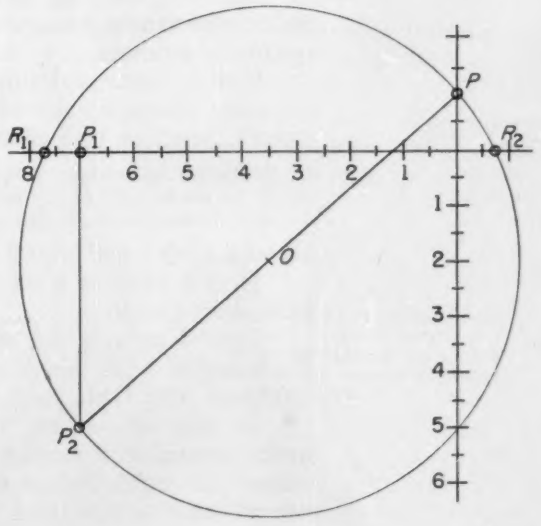
Tips and Techniques

Graphic Solution of Quadratic Equations

Quadratic equations of the form $ax^2 + bx + c = 0$ may be solved by a simple graphical method. As an example, consider the equation $x^2 + 7x - 5$, where $a = 1; b = 7; c = -5$.

1. Lay off point $P = a = 1$ on the vertical axis.
2. Lay off point $P_1 = -b/a = -7$ on the horizontal axis.
3. Directly below P_1, lay off $P_2 = c/a = -5$.
4. Draw line PP_2 and determine its midpoint, O.
5. With center at O, draw a circle of radius OP through P and P_2. Intersections of the circle with the horizontal axis represent roots $R_1 = -7.65$; $R_2 = 0.65$.

—FRANK MURRAY, *Detroit, Mich.*



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AC Motor Control—1

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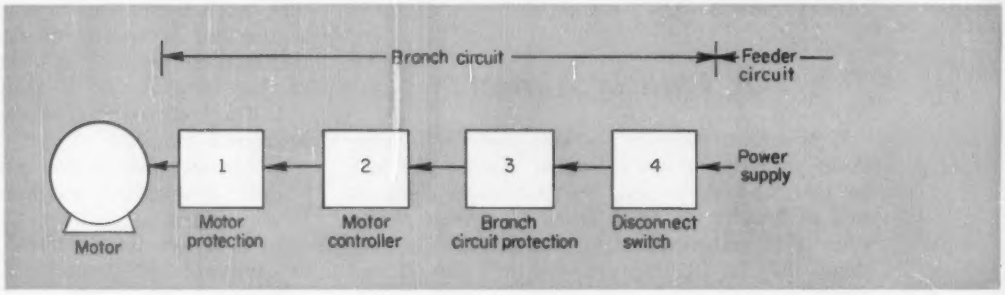
Staff Engineer — Application Engineer
The Clark Controller Co.
Cleveland, Ohio



Five major functions of a motor-control system are:

1. Start and stop electric motors.
2. Protect personnel, motors, and control equipment.
3. Govern motor speed, torque, horsepower, and other characteristics.
4. Maintain proper sequencing of motors, equipment, processes, and/or operations.
5. Sense and correct errors in operation of a motor, machine, or process.

First three functions are provided by the basic units in the block diagram shown here for a simple control system. How these functions are obtained, what kind of equipment is required, and how to select and apply this equipment will be covered in this program of articles.

Unit 1 in the diagram protects the motor from starting or running under overcurrent conditions which could cause overheating and damage to the windings.

Unit 2 starts and stops the motor and also provides the desired operating characteristics of the drive (combination of controller and motor). Selection of a motor controller depends on:

1. Nature of the job.
2. Characteristics of the motor.
3. Characteristics of power supply.
4. Type of environment.
5. Laws, codes, regulations, and standards encompassing an application.

Usually, Unit 1 and Unit 2 are combined.

Unit 3 protects the branch circuit, motor, and associated control from short circuits.

Unit 4 permits the entire branch circuit to be de-energized and disconnected from the power supply. It can be a separate unit or be combined with Unit 3.

In this article program, interest is directed mainly toward the motor controller or starter, Unit 2. Future articles will discuss starting controls for squirrel-cage motors, multiple-speed squirrel-cage motors, wound-rotor motors, and synchronous motors.

To introduce this series, motor characteristics are presented in this first article as an aid to the selection of motor controls. Here are the fundamentals of . . .

Squirrel-Cage Motors

. . . the work horse of ac industrial drives

BEFORE ac motor controls can be skillfully selected, operating and application characteristics of the drive motor must be thoroughly understood. But which type of motor is to be controlled? Are different controls required to obtain similar performance from different motors?

Fortunately, basic control apparatus can be applied to a variety of motor types. Although specific applications may require different controls even for the same motor design, the fundamental characteristics of a representative motor will serve to illustrate the principles of electric motor control.

The most widely used industrial drive motor is the ac polyphase induction type known as the squirrel-cage motor. Its main advantages are:

1. Low initial cost.
2. Uncomplicated, inexpensive control.
3. Low maintenance cost.
4. Design versatility.
5. High efficiency.
6. Reasonably good power factor.

In addition, widespread use of three-phase squirrel-cage motors has been a contributing factor in making low-cost three-phase ac power almost universally available.

The simple and rugged construction that contributes to minimum maintenance is evident in the squirrel-cage rotor, Fig. 1. Basically, it is a cylinder

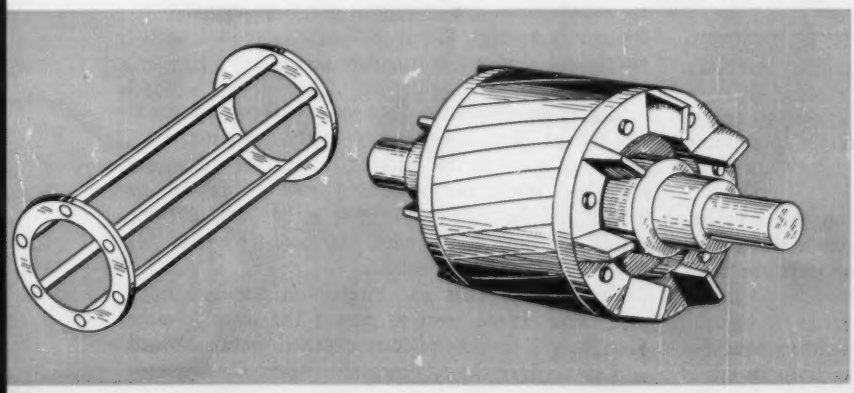


Fig. 1—Sketch of conductor bars attached to short-circuiting end rings and view of a complete squirrel-cage rotor with skewed conductor bars.

formed by a number of aluminum or copper bars which are connected on both ends by heavy rings. The complete rotor appears as a solid cylinder with the conductors placed in parallel slots extending from end to end.

When the stator is energized with alternating current, a rotating magnetic field is established. At standstill, the bars of the rotor are "cut" by the flux lines of this field. As a result, a voltage is induced in the bars and causes currents to flow in them. In turn, the currents in the bars set up a magnetic field with north and south poles in the rotor. Forces of attraction and repulsion between stator and rotor poles set the rotor in motion as it attempts to keep up with the rotating flux of the stator.

The squirrel-cage motor can serve many different applications through design variations which alter such characteristics as speed, slip, torque, horsepower, locked-rotor current, and operating voltage. Characteristics which most influence motor performance are briefly covered here as a background for the specific sections on control apparatus that follow.

Eddy Currents: The rotating magnetic field of the stator induces voltages and currents in the stator and rotor cores as well as in the rotor bars. The core currents that are produced are called eddy currents. Since they provide no benefits but, instead, result in wasted power, an attempt is always made to keep eddy currents at a minimum in motor design.

Nomenclature

C = Coded rating (see Table 3), kva/hp
E = Line voltage, v
f = Frequency of power supply, cps
I_{LR} = Locked rotor current, amp
P = Motor output power, hp
p = Number of poles
S_a = Actual speed of motor, rpm
S_s = Synchronous speed of motor, rpm
s = Slip in motor speed, per cent
T = Motor torque, lb-ft

Rotation: The direction of rotation depends on the power line connections to the motor terminals. Reversing any two incoming lines reverses the motor's direction of rotation.

Speed: Approximate motor speed is determined by the frequency of the power supply and the number of poles for which the stator is wound. The "approximate" motor speed is actually the synchronous speed, or the rate of stator magnetic field rotation, and is found from

$$S_s = \frac{120f}{p} \qquad (1)$$

Actual speed of a squirrel-cage motor is always less than synchronous speed. Synchronous speeds of standard motors for various frequencies are given in Table 1.

Stators of squirrel-cage motors must be built with at least two poles. In addition to reducing speed, an increased number of poles results in reduced horsepower, reduced efficiency, and reduced starting torque. Thus, motors built with many stator poles are both physically larger and more expensive than two-pole motors of the same horsepower, the only benefit being a means of getting lower speed. Because of the disadvantages, it is often better to use gear reduction than an increased number of stator poles when a driven machine requires the slower running speeds.

Another method of reducing motor speed is the use of a lower frequency power supply. However, some of the same disadvantages attributed to an increased number of poles, that is, greater motor size and weight and decreased horsepower, result from this practice.

Table 1—Synchronous Speeds of Squirrel-Cage Motors

Number of Poles	Synchronous Speed (rpm)		
	25 cps	50 cps	60 cps
2	1500	3000	3600
4	750	1500	1800
6	500	1000	1200
8	—	750	900
10	—	600	720
12	—	500	600
14	—	—	514
16	—	—	450

Commercial motors may not be available at all horsepower ratings in the speeds shown.

Where speeds higher than 3600 rpm are desired, a power supply of increased frequency is often used. Many hand power tools are designed for 180 cps to reduce size and weight. Military applications commonly specify 400 to 800 cps to reduce motor weight for a given horsepower.

Slip: The difference between synchronous speed and actual speed is called slip. If the rotor turned at the same speed as the rotating flux in the stator, the rotor bars would not be cutting lines of flux, voltage would not be induced in the rotor bars, current would not flow in the bars, and polarity would not be established in the rotor.

The lack of magnetic interaction between rotor and stator would tend to permit the rotor to slow down until a balance was reached between load and strength of the two magnetic fields. Consequent-

ly, with a fixed load, a fixed speed difference always exists between rotor and the stator field. If load is increased, rotor speed decreases. As a result, the rotating stator field cuts across the rotor bars faster than before. The increased current in the rotor bars produces a stronger rotor field to enable the motor to carry the heavier load.

Slip is generally expressed as a percentage:

$$s = \frac{100(S_s - S_a)}{S_s} \qquad (2)$$

For example, if S_s = 1800 rpm and S_a = 1710 rpm, then s = 100(1800 − 1710)/1800 = 5 per cent slip.

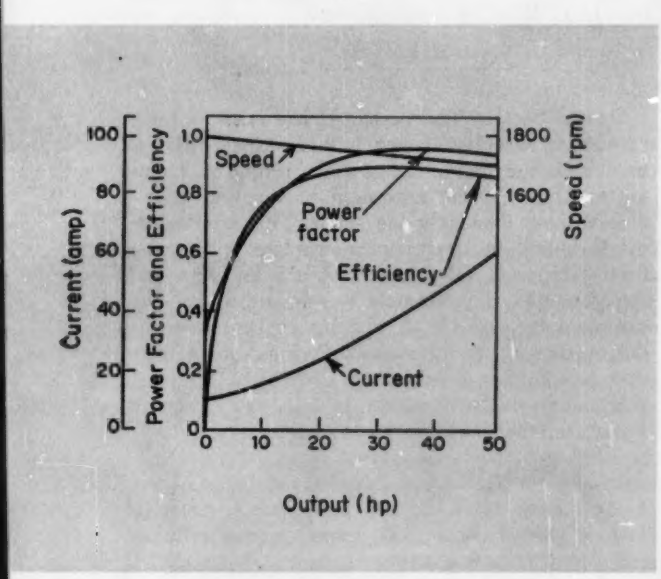


Fig. 2—Representative performance curves for the more common types of squirrel cage motors.

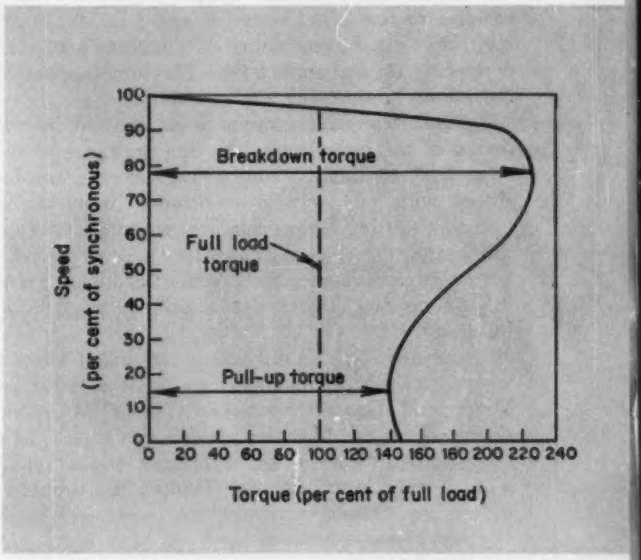


Fig. 3—Typical speed-torque curve for squirrel-cage motor.

Squirrel-cage motors are designed to operate with slip values ranging from less than 5 per cent to about 20 per cent. A motor with slip of 5 per cent or less is called a normal-slip motor. It is also called a constant-speed motor because speed changes very little with load variations. Motors with slip above 5 per cent are used for hard-to-start applications but are less efficient than normal-slip motors.

Efficiency: In terms of a percentage, efficiency is the ratio of useful power output to total power input. The major causes of reduced efficiency are motor electrical losses, which are converted into heat and subsequently limit power output. The effect of losses and slip on efficiency is demonstrated for a 35-hp motor:

EXAMPLE: Determine full-load efficiency of a motor with 5 per cent slip. Power input = 30,120 w; fixed loss in stator copper (based on stator current) = 2636 w.

Power input to rotor = 30,120 − 2636 = 27,484 w.

Rotor loss = rotor input × slip = 27,484 × 0.05 = 1374 w.

Power output = 27,484 − 1374 = 26,110 w, or 26,110/746 = 35 hp.

Efficiency = (power out × 100)/(power in) = (26,110 × 100)/30,120 = 86.7 per cent.

Obviously, operation at maximum efficiency is desirable and generally occurs at full load. The efficiency curve shown in Fig. 2 applies to the 35-hp motor in the example but is typical of efficiency curves for the most common motors. Selection of the proper size motor is important—one that is too small will overheat; one that is too large will operate inefficiently.

Power Factor: Power factor is the ratio of real power to apparent power, or watts divided by volt-amperes. A power factor of 1 or unity is ideal. A power factor less than 1 means that a portion of the current drawn from the power lines is not actually used by the motor to produce work. A typical power factor curve for a motor will reach its peak near full load, as does a typical efficiency curve, Fig. 2.

Torque, Power, and Speed: Motor characteristics of prime importance are torque and power. Torque amounts to a turning effort. Power, or horsepower, takes into account rotational speed and is the rate of doing work. The relationship of these three characteristics is given by

$$P = \frac{TS_a}{5252} \qquad (3)$$

The steady constant torque developed by a motor at rated load is called full-load torque. However, when starting, additional torque is generally required to overcome inertia. Starting torque is often referred to as locked-rotor torque. The relationship of starting torque to full-load torque can be seen in the speed-torque curve in Fig. 3.

Most motors are designed to prevent stalling under sudden overloads. This protection appears in Fig. 3 in the form of high breakdown torque. The inherent design of the motor provides this sharply increased torque whenever an overload forces motor speed to dip. Extended operation at this torque level causes overheating and eventual damage to the motor.

Like all motor characteristics, torque is highly variable in the initial stages of motor design. Starting torque can be established at a high or low level, depending on the application. The same applies to breakdown torque and full-load torque.

Squirrel-cage motor torque is determined by the design of the motor, especially the resistance of the rotor bars. Ordinarily, squirrel-cage motors are designed with relatively low-resistance rotors which give low starting torque and low running slip (approximately 3 per cent at full load). A motor built with a high-resistance rotor will have higher starting torque and higher slip (about 8 per cent at full load).

Unfortunately, it is not possible to design a motor which excels in all characteristics. For this reason, Motor and Generator standards of NEMA (National Electrical Manufacturers Association) have established five basic motor designs which satisfy a variety of torque needs. Typical characteristics of the five classes of motors are shown in Fig. 4.

Table 2 lists applications and the general torque and current specifications for each basic NEMA design.

Locked-Rotor Current: A code letter on the nameplate of every motor is the key to motor starting current. This code letter corresponds to a given locked-rotor kva/hp rating as shown in Table 3. Approximate starting current can be determined by substituting values from Table 3 in

$$I_{LR} = \frac{1000\,P\,C}{1.73\,E} \qquad (4)$$

For example, starting current, or locked-rotor current, of a 7½ hp, 220-v motor, with a nameplate code letter of "G" is, approximately,

$$I_{LR} = \frac{1000(7.5)(6)}{1.73(220)} = 118 \text{ amp}$$

Service Factor: The design characteristic known as service or safety factor is a multiplier that is used with the normal horsepower rating of a motor to arrive at the maximum overloading allowable without damaging the motor. This service factor is found on the motor nameplate and ranges from 1.25 on a 1-hp motor to 1.15 for 3-hp and larger motors. For example, a standard 10-hp motor could be used on an 11.5-hp application without overheating or otherwise suffering damage, barring any further overloading. Ordinarily, however, this safety measure should be used to safeguard against unpredictable overloads.

Insulation: NEMA has classified insulation of motor windings as A, B, and H. Class A materials include treated cotton, silk, paper, plastic, cellulose

Table 2—Characteristics of NEMA-Design Squirrel-Cage Motors

NEMA Design	Torque* (% of full load) Starting	Breakdown	Starting Current	Slip	Description	Applications
A	Normal; 100 to 275	Higher than Design B	Normal	Low	For moderately easy-to-start loads requiring slightly more than full-load starting torque and low slip. Has relatively high breakdown torque to sustain occasional overloads. Used where starting current higher than Design B can be tolerated.	Generators, pumps, machine tools, conveyors, compressors.
B	Normal; 100 to 275	200 to 300	Low	Low	For moderately easy-to-start loads requiring slightly more than full-load starting torque and low slip. Has relatively high breakdown torque to sustain occasional overloads, but lower than Design A. Covers 70 per cent of industrial applications.	Generators, pumps, machine tools, conveyors, compressors, blowers.
C	High; 200 to 250	190 to 225	Low	Low	For hard-to-start loads requiring high starting torque but not requiring high overload demands after reaching running speed. Unsuitable for loads having long accelerating time.	Escalators, pulverizers, compressors, conveyors.
D	Very high; 275 max	....	Low	High	For hard-to-start, intermittent loads. Has no defined breakdown torque point. Surge loads cause appreciable decrease in speed but high torque recovers speed rapidly.	Cranes, elevators, centrifuges, punch presses, fly-wheel machines.
F	Low; 125 max	Low; 135 max	Very low	Low	For easy-to-start loads where low locked-rotor current is required. Has lower torque values than Design B except at full load. Made in 30 hp sizes and larger. Check motor manufacturer when long acceleration is necessary.	Large fans, blowers, compressors.

*Specific value depends on actual horsepower rating of motor.

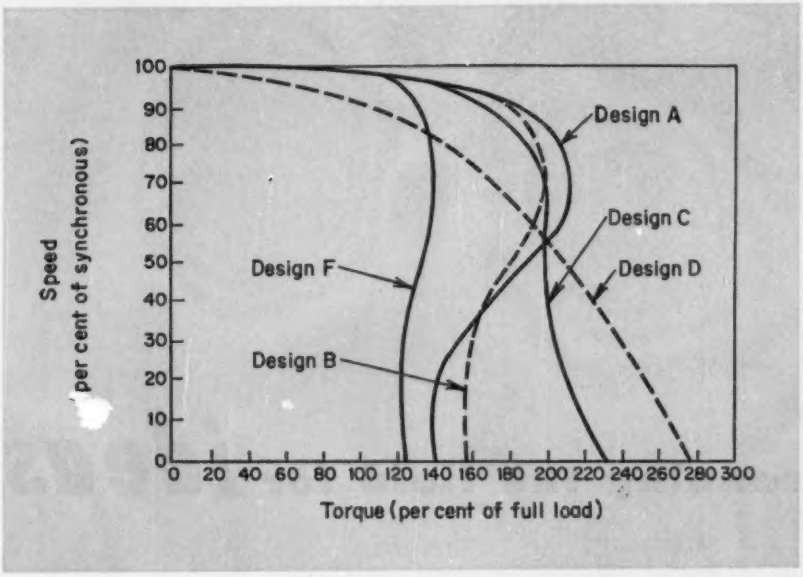


Fig. 4—Typical speed-torque curves for five basic NEMA squirrel-cage motor designs.

derivatives, and varnishes, all of which are satisfactory for standard temperature rises of 40 C in open motors and 55 C in enclosed types. (Temperature rises are based on a maximum ambient temperature of 40 C.) Class B materials include glass fiber, mica, and asbestos, and other materials which have been shown to be satisfactory for motors operating at temperature rises of 70 to 75 C. Class H insulation, including materials such as silicones, is satisfactory for temperature rises of more than 100 C but is costly.

Service Conditions: NEMA has divided the broad range of service conditions into three classes: Usual, more favorable than usual, less favorable than usual. Only the two most frequently encountered are described here.

USUAL: Most squirrel-cage motors today are classified as general-purpose motors. They are offered in standard sizes with standard operating characteristics. Their rated temperature rise is 40 C; that is, motor temperature may rise 40 C above room temperature without damage to the motor. Service conditions under which such motors are designed to operate are:

1. Ambient or room temperature not exceeding 40 C.
2. Voltage variation not exceeding plus or minus 10 per cent of nameplate rating.
3. Frequency variation not exceeding plus or minus 5 per cent of nameplate rating.
4. Combined variation of frequency and voltage not exceeding plus or minus 10 per cent, provided that frequency variation is within the 5 per cent limitation.
5. Altitude not exceeding 3300 ft.
6. Freedom from dust, moisture, fumes, or interference to normal ventilation of the motor.

High ambient temperatures, large voltage variations, high altitude operation, and restricted ventilation lead to motor overheating. Frequency variations affect speed and torque and are also likely to result in overheating. Where conditions exceed the recommended limits, motors with higher horsepower rating may provide satisfactory operation. If explosive or combustible dust or gases are present, general-purpose motors must not be used.

Table 3—Code Letters for Locked-Rotor KVA

Code Letter	Rating* kva/hp	Code Letter	Rating* kva/hp
A	0–3.15	L	9.00–10.0
B	3.15–3.55	M	10.0–11.2
C	3.55–4.00	N	11.2–12.5
D	4.00–4.50	P	12.5–14.0
E	4.50–5.00	R	14.0–16.0
F	5.00–5.60	S	16.0–18.0
G	5.60–6.30	T	18.0–20.0
H	6.30–7.10	U	20.0–22.4
J	7.10–8.00	V	22.4/Up
K	8.00–9.00		

*Range of a rating includes the lower figure up to, but not including, the higher figure.
From NEMA publication MG 1-1959, par. MG 1-2.15.

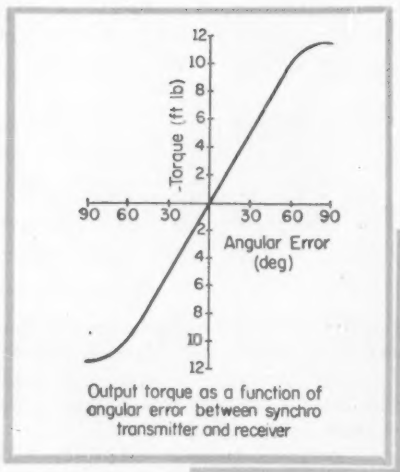
LESS FAVORABLE THAN USUAL: Where conditions are other than "usual," definite-purpose motors or special-purpose motors must generally be used. Definite-purpose motors are standard in construction and operating characteristics but are specially classified because of the nature of the service conditions or application. Special-purpose motors have special operating characteristics or construction and are designed for special applications.

Service conditions that are less favorable than usual include: Chemical fumes, combustible or explosive dust, gritty or electrically conducting dust, lint, steam, inflammable or explosive gases, temperatures below 10 C, oil vapor, salt air, external shock or vibration, damp atmosphere, poor ventilation.

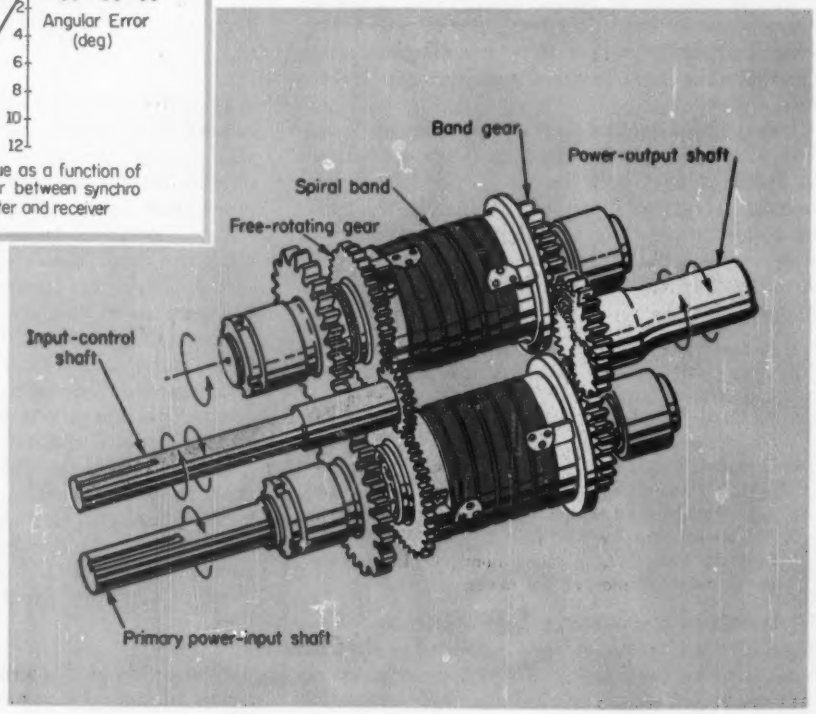
Next article in this series will cover across-the-line starters for squirrel-cage motors.

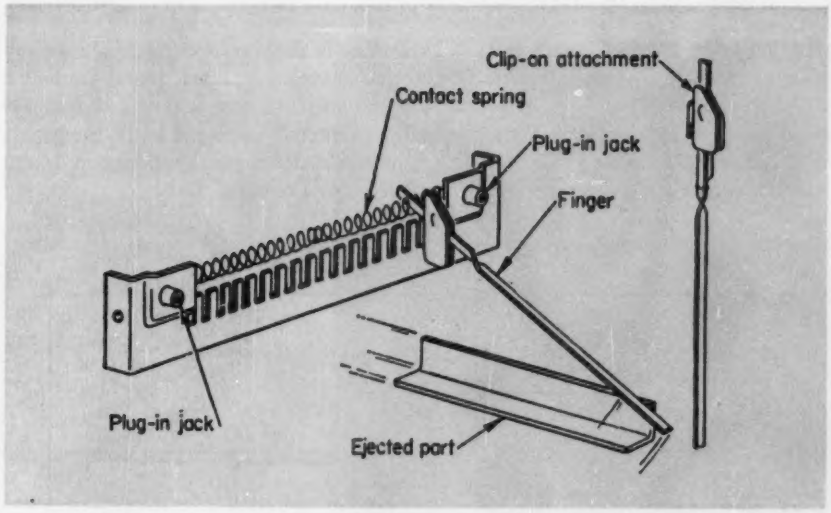
scanning the field for *ideas*

Mechanical power amplifier uses twin windlass drums, rotating in opposite directions, to provide controlled power output in mechanical servo drive. The windlass drums are driven at constant speed by the power source. The input control shaft, through its pinion, drives the free-rotating gears. As the gears rotate, the attached arm on one of the gears engages its spiral band and winds it into contact with the drum. (The opposite band is moved away from the drum.) Power from the primary source is then transmitted through the band gear to the output shaft. Principle employed in mechanical power amplifier developed by Seneca Falls Machine Co., Seneca Falls, N. Y.



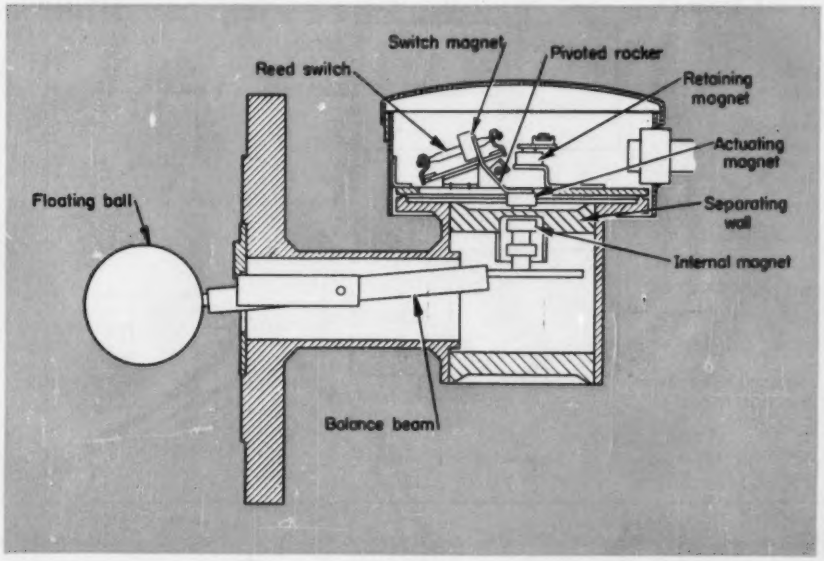
Output torque as a function of angular error between synchro transmitter and receiver





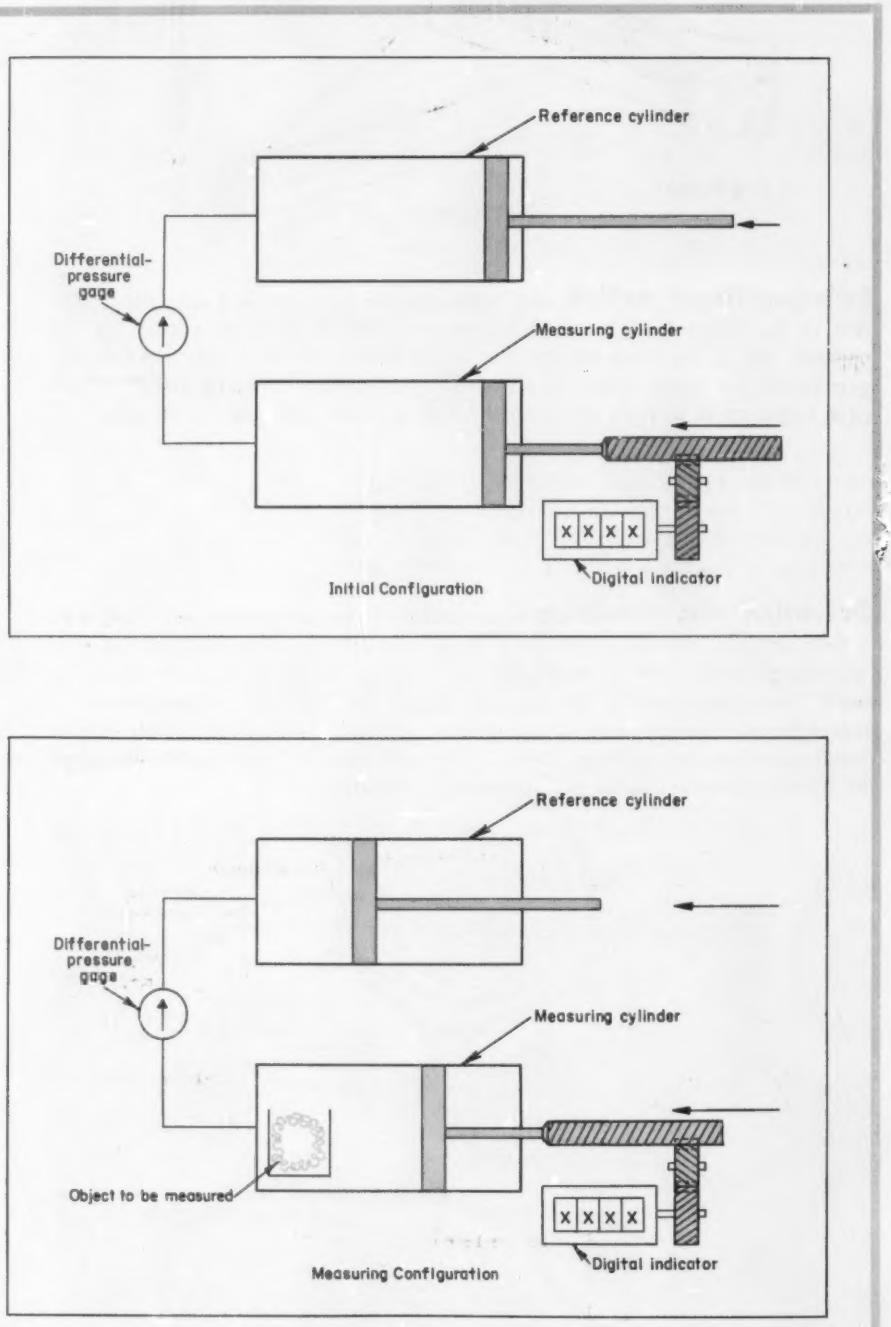
Swinging-finger switch uses same arm for detection and actuation. Motion of the object being detected rotates the finger so that the portion on the opposite side of the pivot meshes into a coil spring contact. After the detected part passes, the finger returns to an upright position and opens the circuit. Principle employed in detector developed by Rehrig Safety Controls, Los Angeles.

Detention plus actuation is provided by a retaining magnet combined with a float-actuated internal magnet in a liquid-level control. Float ball position controls the position of the internal magnet in relation to the nonmagnetic separating wall. Relative position of the internal magnet and the retaining magnet determines the position of the actuating magnet. Alternate position of switch magnet opens or closes the reed-type switch. Principle employed in monitor developed by Siemens-Schuckertwerke AG, Erlangen, Germany.

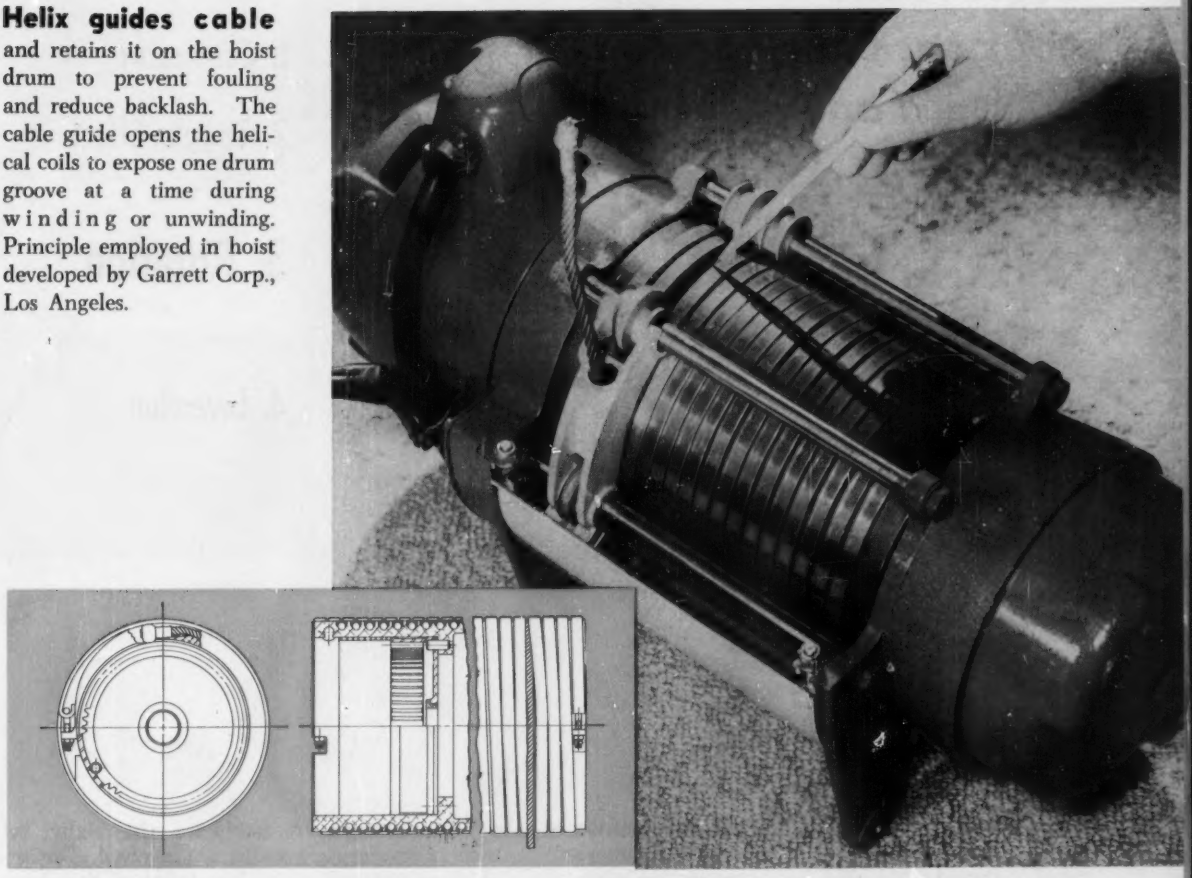


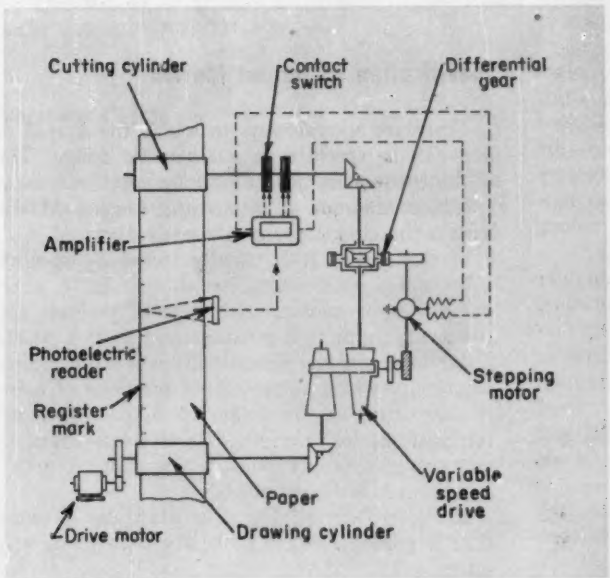
SCANNING THE FIELD FOR IDEAS

Pneumatic volume meter compresses air to measure volume of sample object. Piston in the cylinder containing the sample is adjusted until air pressure equals the pressure in a connected reference cylinder. Relative position of the piston in the two cylinders is then a function of the volume of the specimen. Direct digital readout of the specimen volume is provided mechanically. Principle employed in air-comparison pycnometer developed by Beckman Instruments Inc., Fullerton, Calif.



Helix guides cable and retains it on the hoist drum to prevent fouling and reduce backlash. The cable guide opens the helical coils to expose one drum groove at a time during winding or unwinding. Principle employed in hoist developed by Garrett Corp., Los Angeles.





Pulsed servo loop synchronizes operation of a paper-cutting machine. Register marks along one edge of the moving paper strip are detected by a photoelectric reader. If the cutting cylinder is synchronized with the register marks, a rotary contact switch blocks the pulses from the photoelectric reader. However, if pulses and cylinder are not synchronized, the pulses pass through the rotary switch to the appropriate side of the two-channel amplifier. The amplifier output actuates a stepping motor to adjust both the angular relationship and the speed ratio between the drive motor and the cutting cylinder. Principle employed in cutting machine designed by Allgemeine Elektricitaets-Gesellschaft, Berlin, Germany.

How to use four basic concepts to speed and improve

Mechanism Design

1. Constraint
2. Toggle Effect
3. Rotation
4. Inversion

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TWO kinds of motion are commonplace in mechanisms—linear motion and angular motion. A rigid body has linear motion when all the points of it move equal distances in the same direction simultaneously. Accordingly, if a rigid machine part is constrained to have only linear motion, the motion of every point in it is determined when the magnitudes and directions of the motion of one point of it are known.

A rigid body has angular motion if two points in it move unequal distances in the same time. Whereas the motion of only one point is sufficient to establish the linear motion of a rigid body, the motions of at least two points in it are necessary to establish its angular motion. Whereas linear motions pertain to equalities in the motions of points, angular motions pertain to their inequalities.[1]

Viewed in another way, a rigid body has angular motion if at least two points in it undergo unequal motions simultaneously. The inequality in the motions of the two points is the relative motion between them. This relative motion must be a pure rotation because any two points of a rigid body remain a fixed distance apart in any motion of the body. If and when inequalities in the motion of all points do become equalities, then the resultant linear motion is regarded as a limiting condition in which the relative rotation between any two points is zero.

[1]References are tabulated at end of article.

When linkages are considered, the relative rotations of several rigid bodies are involved. The study of these rotations is the foundation of the classical development of kinematic synthesis: Both for the older graphical techniques[2,3,4,5] developed primarily in Germany, and for the newer analytical techniques,[5,6,7] developed primarily in the United States.

Specification of Output Motion

There are several ways in which the output motion can be specified in a kinematic design. Three of the commonest types of motion specifications are:

1. *Co-ordination of Input and Output Motions*: This is the motion problem already discussed in Part 2 of this series. It is usually stated by specifying a functional relationship, or schedule curve, of output vs. input motion. This type of problem arises when the input is a constant torque or a constant linear force and the desired output is a force, torque, or velocity which varies during the cycle of motion. It also arises in the design of function-generating mechanisms, for example, a mechanism whose output angle is proportional to the sine, tangent, or logarithm of the input angle.

2. *Point Tracing*: Fig. 21*a* illustrates a point *E* that is guided along a path from one point to another.

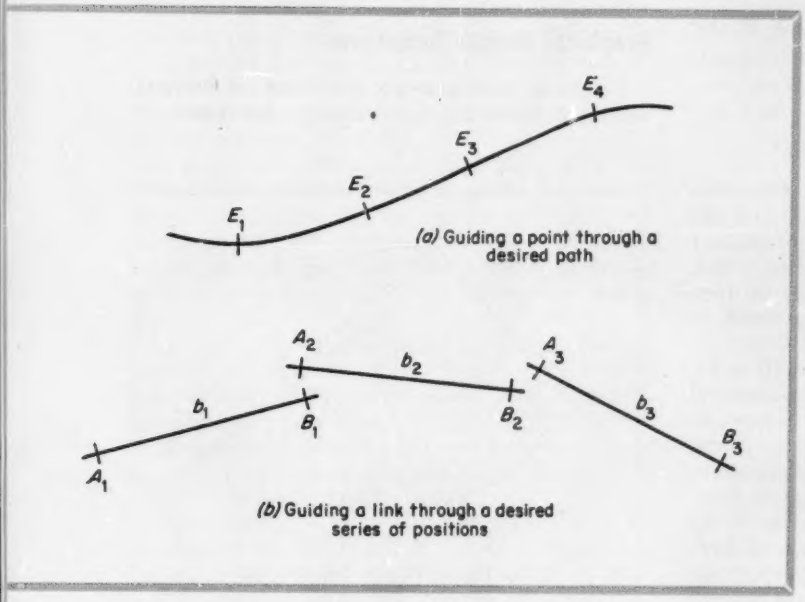


Fig. 21—Specifications of output motion.

3. *Link Guiding*: Fig. 21*b* illustrates the motion of a link as it is guided through successive positions b_1, b_2, and b_3. As explained in Part 1, planar motion of a link can be specified by the motion of any line segment which is fixed in, or rigidly attached to, the link. Thus, in Fig. 21*b*, the motion of link *b* is specified by the motion of the line segment *AB*, i.e., by the paths of points *A* and *B*.

Precision Points

With a cam mechanism, output-motion specifications can be fulfilled exactly, up to the limit of machining accuracy, since a cam curve can be constructed to correspond to a prescribed path or schedule curve at an infinite number of points. In a link mechanism, however, there are only a limited number of adjustable parameters, and therefore it is possible, in general, to match a prescribed path or schedule curve in only a finite number of points.

The points where the linkage is designed to match the specifications are called precision points.[7] The greater the complexity of the linkage, the greater is the number of adjustable parameters, and hence the greater is the number of precision points which are achievable. As shown in *Determining the Number of Precision Points*, the number of precision points available with a given linkage can readily be

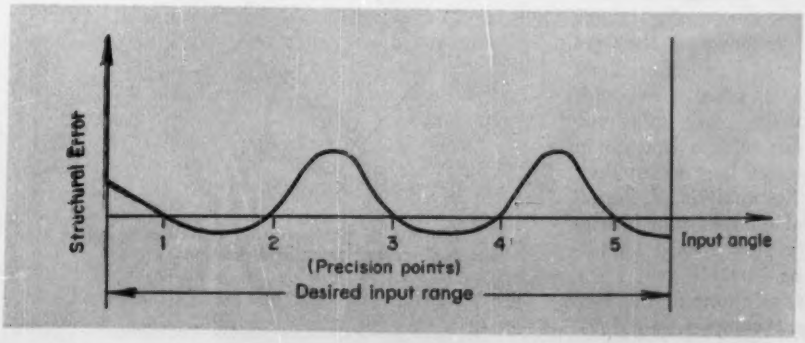


Fig. 22—Plot of structural error to illustrate precision points.

determined from an analytical formulation of the linkage-design problem.

Spacing of Precision Points

Structural error of a linkage is the error between the desired point path or schedule curve and the actual point path or schedule curve as obtained from a linkage with no machining errors. With the aid of digital computers it is possible in some cases to design linkages having structural errors of less than a minute of arc.[7]

While the structural error can, in general, be reduced to zero at the precision points, the structural error in the intervals between precision points can be minimized by optimum spacing of precision points. For example, a hypothetical plot of structural error vs input crank angle for a trial linkage design is shown in Fig. 22. Since the greatest structural error occurs between the second and third and between the fourth and fifth precision points, it is probable that the structural error can be reduced by spacing these pairs of points closer together and the other pairs farther apart.

If the goal is to minimize the peak value of structural error in the whole range of the input crank angle, then the respacing should be continued until the maximum error in each interval between precision points and in each of the two end intervals is the same. A digital computer program is available for performing this series of computations automatically in the design of a four-bar linkage for co-ordination of angular displacements of input and output cranks.[7]

Analytical Design Techniques

The analytical procedure for designing a linkage is to solve the $2NL$ (for planar mechanisms) or $3NL$ (for spatial mechanisms) loop equations for the parameters[6,7,8,11] of the linkage. Digital-computer programs are available for the problems of Examples 1 and 4, as well as for synthesis of a spatial four-bar linkage for co-ordination of input and output angular displacements.

These programs provide by far the most accurate method available for refining the design of a linkage to minimize the structural error. However, they are not suitable for an initial survey of a design problem. A digital computer, for example, when faced with an unreasonable design problem, may solve the problem anyway and come out with a linkage in which one link is 10,000 times as long as another. For this reason, the qualitative analysis of Part 2 and the approximate graphical analysis that follows are valuable as a preliminary step toward digital-computer programs as well as in their own right.

For more complex linkages, solutions of the loop equations become increasingly complex, and no digital-computer programs are yet available. Under such circumstances, graphical techniques are the only available methods.

Graphical Design Techniques

Graphical techniques for the design of linkages, developed primarily in Germany, are based on

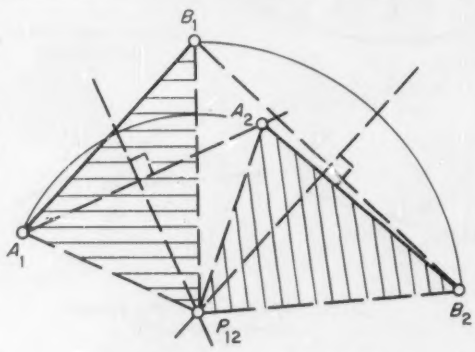


Fig. 23—Guiding a link through two prescribed positions.

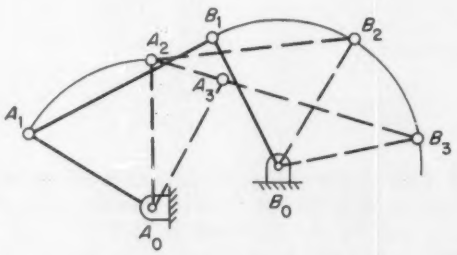


Fig. 24—Guiding a link through three prescribed positions.

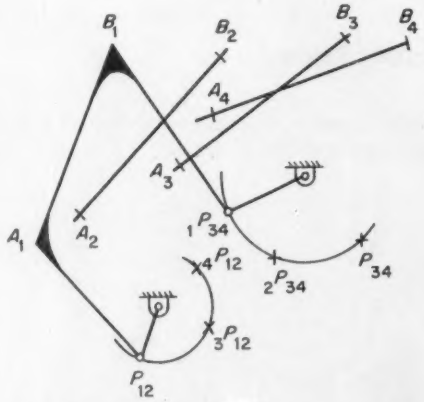


Fig. 25—Use of point-position reduction to guide a link through four prescribed positions.

elementary geometrical constructions. Consider the problem of guiding a link AB through a desired sequence of positions in a plane, Fig. 21*b*. Example 5 illustrates a solution for five positions, i.e., for five precision points, when link AB is made the coupler of a four-bar linkage. If less than five positions are specified, additional specifications such as space requirements or transmission-angle requirements can be imposed upon the design.

If only two positions, A_1B_1 and A_2B_2, of a link AB are prescribed, the guidance can be achieved simply by pivoting the link to the machine frame at the point of intersection of the perpendicular bisectors of A_1A_2 and B_1B_2. This point is called the pole for positions 1 and 2 and is denoted by P_{12}, Fig. 23.

If three positions of AB are prescribed, then in general the link can not be guided through these positions by using a single fixed pivot. However, since a circle can be drawn through any three points, a circle through points A_1, A_2, and A_3 with center at A_0 and a circle through points B_1, B_2, and B_3 with center at B_0 can be constructed.

Next, introduce guide link A_0A, attached to the machine frame by the fixed pivot at A_0 and attached to link AB by the moving pivot at A. Similarly, introduce guide link B_0B with a fixed pivot at B_0 and a moving pivot at B. As shown in Fig. 24, link AB is now the coupler of a four-bar linkage which is constrained to pass through the desired three positions. Instead of A and B, any two points on link AB as the moving pivots may have been chosen. Thus the moving pivots can be matched to other design requirements.

If four positions of AB are prescribed, random selection of any two points on link AB as moving pivots for guide links is no longer permissible since it is not possible to draw a circle through four arbitrary points. This is the stage at which simple geometry leaves off and the classical theory of kinematic synthesis begins.

Burmester[2,3,12,13] discovered a geometric curve, known as the circle-point curve, which is the locus of the points on the link whose four positions lie on a circle. A corresponding curve, known as the center curve, is the locus of points on the machine frame which are the centers of such circles and can therefore be used as fixed pivots. For a given problem these curves can be drawn up point-by-point, starting from pole P_{12} and analogously defined poles P_{13}, P_{14}, P_{23}, P_{24}, and P_{34} and using geometrical rules.[13] After learning these rules, an engineer or draftsman can locate enough points to define a circle-point or center curve in about an hour.

Instead of the circle-point and center curves, elementary methods can still be used to find points to guide a link through four positions. One method is to use trial-and-error aided by interpolation: If A_4 lies outside the circle through A_1, A_2, and A_3, while B_4 lies inside the circle through B_1, B_2, and B_3, a search can be made between A and B for a point C for which C_1, C_2, C_3, and C_4 all lie on the same circle. This method is conveniently carried out by using a vellum overlay of the moving member and moving it through the desired four positions relative to the fixed member. This overlay method[14,15] has the advantage that it can be used to investigate pivot points for a continuous range of motion as well as for distinct positions of the moving member.

A second elementary method for finding points to guide a link through four positions is to use one of the poles as a moving pivot. Since P_{12} occupies the same position at positions 1 and 2 of the link, it passes through only three positions, which may be denoted by P_{12}, ${}_3P_{12}$, and ${}_4P_{12}$, when the link passes through positions 1, 2, 3, and 4. Therefore P_{12} can be used as a moving pivot and the center of the circle through P_{12} ${}_3P_{12}$, and ${}_4P_{12}$ can be used as a fixed pivot, Fig. 25. A similar argument applies to the other five poles. This use of poles to reduce the number of positions through which a circle must be passed has been given the name point-position reduction.[3,16]

If five positions of AB are prescribed, there are

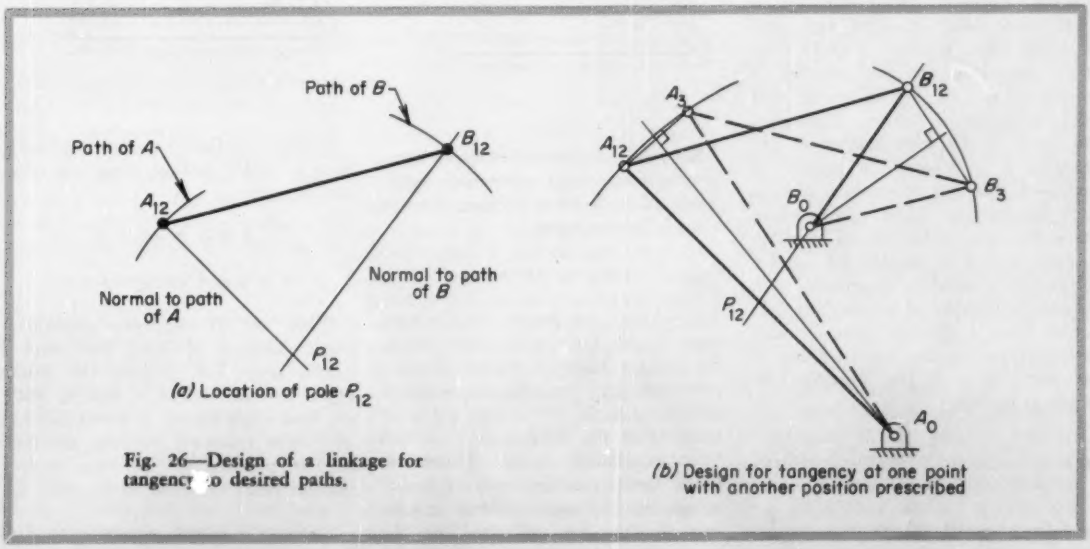


Fig. 26—Design of a linkage for tangency to desired paths.

at most a finite number of points on link AB that can be used as moving pivots for guide links. The classical method of finding these points is to draw the circle-point curve for positions 1, 2, 3, 4 and the circle-point curve for positions 1, 2, 3, 5 and find their points of intersection. Besides poles P_{12}, P_{13}, and P_{23} (which in general cannot be used as moving pivots for guiding the link through all five positions), there will be at most four points of intersection which can be used as moving pivots. These points are known as Burmester points.[12,13] There is a corresponding set of Burmester points, found as intersections of center curves, which can be used as fixed pivots.

Infinitesimally Close Positions

Often it is desirable to guide link AB so that the paths of points A and B will be tangent to desired paths rather than simply crossing these paths at several distinct points. To make A and B tangent to desired paths, prescribe positions 1 and 2 infinitesimally close together at the respective points of tangency of the paths of A and B to their desired paths. These points can be denoted by A_{12} and B_{12}, respectively. Pole P_{12} becomes the instantaneous center of rotation for link AB, Fig. 26*a*. Any point on the normal to the path of A at the point of tangency

Determining the Number

Analytically, a problem in linkage design can be expressed by writing a set of simultaneous vector equations in which the desired points on paths or schedule curves are included as known quantities, and the adjustable parameters of the linkage are included as unknowns. For each position of the linkage, let L denote the number of independent vector equations, or loop equations,[9,10] needed to specify the positions of all the links as functions of the input position. Also, denote by N the number of precision points, as well as the number of different positions in which the linkage is required to meet the prescribed conditions.

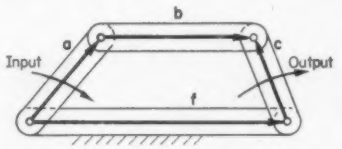
Since a planar vector equation is really two scalar equations and since a spatial vector equation is really three scalar equations, the total number of equations is $2NL$ for a planar and $3NL$ for a spatial linkage. This must be equal to the total number of unknowns. If c denotes the number of unknown constants (parameters such as link lengths and initial angles, which have the same value for all precision points) and if v denotes the number of unknown variables (parameters such as angular positions of intermediate links which have a different value for each precision point), the total number of unknowns is $c + Nv$. Therefore, for a planar linkage,

$$N = \frac{c}{2L - v} \qquad (8)$$

and for a spatial linkage,

$$N = \frac{c}{3L - v} \qquad (9)$$

In vector equations, a line joining two points on a rigid link is represented by a vector having constant magnitude and a different direction for each precision point; a relative sliding motion is represented by a vector having a different magnitude for each precision point. For planar linkages, the equations can be conveniently written in complex-number notation.[8]

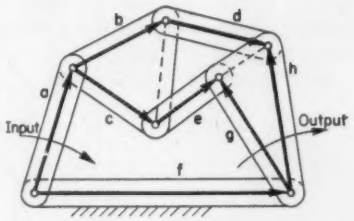


Example 1: For co-ordination of angular displacements of input and output cranks of a four-bar linkage, there is a single loop equation,

$$\mathbf{a} + \mathbf{b} - \mathbf{c} = \mathbf{f}$$

Assume that the initial angular positions of the input and output cranks (in position 1 of the linkage) are not prescribed, but that the displacements from these initial positions in the other positions of the linkage are prescribed by the schedule curve. These two initial angular positions may be treated as unknown constants. Since angular displacements are unaffected by the linear scale of the linkage, the length of one link can be chosen arbitrarily. Then, lengths of the other three links are unknown constants. There is one unknown variable: The angular position of the coupler. For use in Equation 8,

$$c = 5, v = 1, L = 1; N = 5$$



Example 2: For the same problem, using a six-bar linkage, there are two loop equations

$$\mathbf{a} + \mathbf{b} + \mathbf{d} - \mathbf{h} = \mathbf{f}$$

$$\mathbf{a} + \mathbf{c} + \mathbf{e} - \mathbf{g} = \mathbf{f}$$

There are 11 unknown constants: Initial positions of input and output cranks, seven link lengths, the fixed angle between vectors **b** and **e**, and the fixed angle betwen vectors **g** and **h**. The three unknown variables are the angular positions of the three intermediate links. For use in Equation 8,

$$c = 11, v = 3, L = 2; N = 11$$

may be used as the fixed center, A_0, and any point on the normal to the path of B at the point of tangency may be used as the fixed center, B_0.[2]

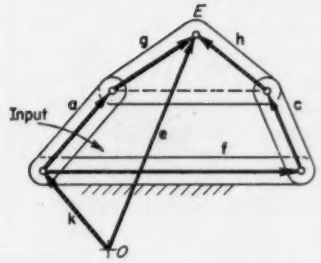
To make A and B be tangent to desired paths in one position and pass through another position without any tangency requirement, identify the first position as positions 1 and 2 (infinitesimally close together) and the position with no tangency requirement as position 3, Fig. 26*b*. Then, if A is to be used as a moving pivot, fixed pivot A_0 is located at the intersection of normal $A_{12}P_{12}$ and the perpendicular bisector to $A_{12}A_3$. Fixed pivot B_0 is found in the same way.

To make A and B tangent to desired paths in two positions, identify the first position as positions 1 and 2 (infinitesimally close together) and the second as positions 3 and 4 (also infinitesimally close together). No longer is it possible to choose any two points on link AB as moving pivots for guide links. Instead, find a point C for which the intersection of normals $C_{12}P_{12}$ and $C_{34}P_{34}$ is equidistant from C_{12} and C_{34}. This intersection may then be used as fixed pivot C_0.

Second point D and its fixed pivot D_0 may be found in the same way. These points can be readily found by a trial-and-error procedure. To avoid trial-and-error, the circle-point curve or center curve for the four link positions can be plotted; in this problem, these assume a simple form because poles P_{13}, P_{14}, P_{23}, and P_{24} all coincide.

To make A and B hug their desired paths even more closely in the neighborhood of points A_1 and B_1, three positions of the link can be prescribed infinitesimally close together. Then, since the circle

of Precision Points



Example 3: To guide point E on the coupler of a four-bar linkage through a desired path, the prescribed path may be defined by vector **e** drawn from origin 0 to point E. Then there are two independent loop equations:

$$\mathbf{e} = \mathbf{k} + \mathbf{a} + \mathbf{g}$$

$$\mathbf{e} = \mathbf{k} + \mathbf{f} + \mathbf{c} + \mathbf{h}$$

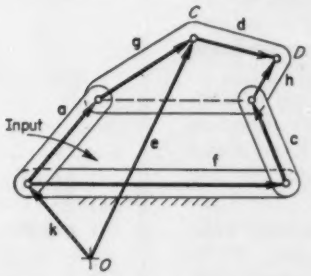
If none of the angular positions of the other links is prescribed, there are nine unknown constants: The lengths of the six vectors, the angular positions of fixed vectors **k** and **f**, and the fixed angle between **g** and **h**. The three unknown variables are the angular positions of three movable links. By Equation 8,

$$c = 9, v = 3, L = 2; N = 9$$

Example 4: In the previous example, if it is desired to make E traverse the various portions of its path in prescribed relative time intervals, the angular displacement of the input crank from position 1 to each of the other positions can be prescribed. Then, the input crank angle is no longer an unknown variable but the initial crank angle becomes an unknown constant.

Now,

$$c = 10, v = 2, L = 2; N = 5$$



Example 5: To guide the coupler CD of a four-bar linkage through a prescribed sequence of positions, there are two loop equations:

$$\mathbf{k} + \mathbf{a} + \mathbf{g} = \mathbf{e}$$

$$\mathbf{k} + \mathbf{f} + \mathbf{c} + \mathbf{h} - \mathbf{d} = \mathbf{e}$$

where **e** = OC and **d** = CD. If none of the angular positions of the other links is prescribed, there are ten unknown constants: The lengths of all vectors except **d**, the angular positions of fixed vectors **k** and **f**, and the initial angular positions of **g** and **h**. There are only two unknown variables—angular positions of input and output links—since the angular displacement of the coupler is given by prescribed vector **d**.

When Equation 8 is solved,

$$c = 10, v = 2, L = 2; N = 5$$

Example 6: In the previous example, if the input crank displacements corresponding to displacements of CD from position 1 are prescribed, there is one less unknown variable and one more unknown constant. For this case,

$$c = 11, v = 1, L = 2; N = 3\tfrac{1}{2}$$

This fractional result means that actually there can be only three precision points, but since this would give 12 scalar equations with 14 unknowns, the value of two unknowns may be chosen arbitrarily.

Remarks: The foregoing analysis still applies when some of the precision points are infinitesimally close together. By bringing two precision points infinitesimally close together, both a position specification and a velocity or tangency specification can be imposed.

Possibilities include, in Examples 1 and 2, the derivative of the output angle with respect to the input angle, or the slope of the schedule curve of output vs input; in Example 3, the tangent to the path of point E at a given location; in Example 4, the magnitude and direction of the velocity of E for a given angular velocity of the input crank.

By bringing three precision points infinitesimally close together, acceleration or curvature specifications like the following can also be imposed: In Examples 1 and 2, the second derivative of the output angle with respect to the input angle; in Example 3, the radius of curvature of the path of point E at a given location; in Example 4, magnitude and direction of the acceleration of E for a given angular velocity and acceleration of the input crank.

of curvature for a curve at a given point is defined as the circle which has third-order contact with the curve (i.e., which coincides with the curve at three points infinitesimally close together), points A_0 and B_0 are located at the centers of curvature of the curves at point A_{123} and B_{123}, respectively. Since there is a circle of curvature for any point on a curve, any two points on the link can be used as moving pivots, and their centers of curvature are the corresponding fixed pivots.

If it is desired to specify the curvature of the path of point C on a link when center of curvature C_0 is inaccessible, then any other points A and B on the link can be used as moving centers. The relation between distances AA_0, BB_0, and CC_0 is given by the Euler-Savary Equation:[2,17,18]

$$\left(\frac{1}{PA}-\frac{1}{PA_0}\right)\sin\psi_A=\left(\frac{1}{PB}-\frac{1}{PB_0}\right)\sin\psi_B=\left(\frac{1}{PC}-\frac{1}{PC_0}\right)\sin\psi_C \quad \ldots(10)$$

where P is the instantaneous center of rotation (located at intersection of AA_0, BB_0, and CC_0), ψ_A is the angle between PA and the pole tangent (the tangent to the path of P when the link is moved toward a new position), and ψ_B and ψ_C are defined similarly to ψ_A. If the direction of the pole tangent cannot be determined by inspection, it can be found by solving for one of these angles.

Distances PA, PB, PC are always taken as positive. Then, PA_0 is taken as positive when A and A_0 are on the same side of P and negative when A and A_0 are on opposite sides of P; similarly for PB_0 and PC_0.

For even closer approximation to a desired path, four infinitesimally close positions of a link may be prescribed. Use of any point on the link as a moving pivot is no longer permitted, since in general it is not possible to make a circle have fourth-order contact with a curve. Only points whose paths have stationary values of curvature at this point can be used as the moving pivot; their locus is a curve known as the circling-point curve (by analogy with the circle-point curve) and the locus of their centers is known as the centering curve[2] (by analogy with the center curve). These two curves are defined by cubic equations and are sometimes called the cubics of stationary curvature.

A simpler but less general method of finding points whose paths coincide with circles in four infinitesimally close positions is to use a symmetrical linkage such as the one shown in Fig. 27. Since points on the axis of symmetry have paths which are symmetrical about this axis, they must have even-order contact with any circle whose center is on this axis. For any point C on the axis of symmetry, center C_0 of the circle having third-order contact with the path of C can be found by Equation 10. By the symmetry of the linkage, this circle will automatically have fourth-order contact with the curve.

Conversely, Equation 10 can be used to find point C on the axis of symmetry having a desired radius of curvature. For example, to design an approximate straight-line mechanism, the point whose path has infinite radius of curvature can be found. This point is shown as point D, Fig. 27, and linkage A_0ADBB_0 is a Chebyshev straight-line mechanism. As might be expected, the axis of symmetry is actually a portion of the circling-point curve for this position of link AB.

Going one step further, it is possible to find a finite number of points on a link whose paths have fifth-order contact with a circle. These points are called Burmester points by analogy with the theory

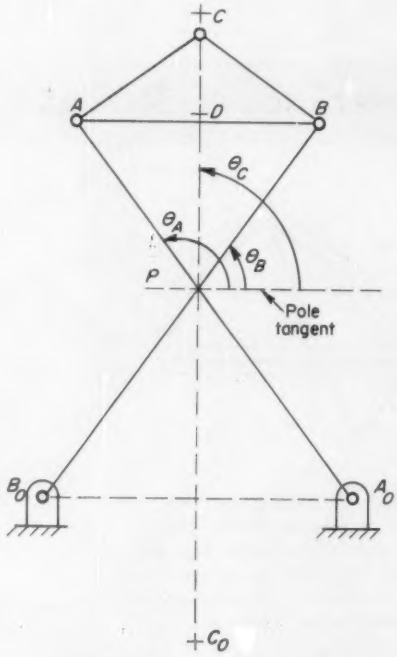


Fig. 27—Curvature relationships in a symmetrical linkage.

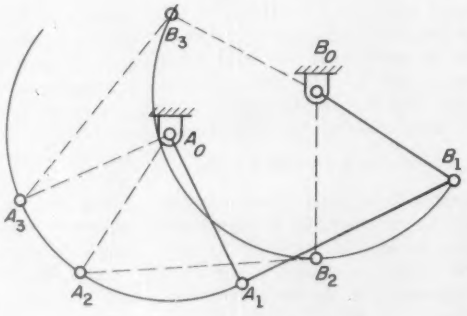


Fig. 28 — Spurious solution for three positions of a link.

of five finitely separated positions of a link. Both graphical and analytical techniques exist for locating these points.[19]

Graphical Design of Complex Linkages

The graphical techniques discussed up to now have dealt with design of a four-bar linkage to guide a coupler through a desired path. When the desired number of positions exceeds five, or when an investigation shows that the desired motion cannot be achieved with a four-bar linkage, then a more complex linkage must be considered. Unfortunately there are at present no general methods for the design of a linkage more complex than a four-bar linkage, but there are some special methods that can be used.

One basic approach for six-bar linkages is to choose one four-bar linkage in the six-bar linkage and design it first in accordance with the space requirements of the particular application. Then the properties of this four-bar linkage are used in the design of the remaining two links. This approach may be used to design a dwell linkage by means of point C on the coupler of a four-bar linkage whose path has a portion approximating a circular arc. By locating moving pivots at C and at the center of the arc, the latter pivot is made to dwell while C traverses the circular-arc portion of its path.[20]

A second basic approach is to use successive applications of point-position reduction.[3] By this method a linkage can be designed to guide a link through any desired number of positions, but the complexity of the linkage increases with the number of positions. Because this method is not completely general, the number of precision points which can be achieved with a linkage of given complexity using point-position reduction is less than the maximum number given by the method illustrated by the example. Or, to put it in another way, a linkage of greater complexity is required to achieve a given number of precision points by point-position reduction than would be required if completely general methods were available.

Spatial Mechanisms

In a link moving in three dimensions, the motion of one point relative to any other point is still a pure rotation, but the link as a whole may also have a translational motion perpendicular to the plane of rotation. Thus, the most general motion of the link relative to the adjacent link is a screw motion rather than a rotation in one plane.[21]

Geometrical design methods for guiding the coupler of a spatial four-bar linkage through a prescribed sequence of positions utilize this principle.[22] Analytical design methods use a dual number system, in which a generalized rotation represents both a rotation and a translation, to write the loop equations of the system.[23]

A special spatial mechanism is the spatial four-bar linkage in which the input and output cranks have pure rotations about nonparallel axes and the coupler is connected to the input and output cranks by ball-and-socket joints. Design of the mechanism can be handled, both graphically[24] and analytically,[11] by a straightforward extension of methods used for planar four-bar linkages.

Spurious Solutions

Both analytical and graphical design techniques have one pitfall. This is the possibility of spurious solutions, Fig. 28. Many linkages can be connected in two or more configurations, but once connected, must continue to operate in the same configuration in which they were connected. However, neither the analytical nor the graphical design techniques are able to take this into account. Mathematically, the linkage in Fig. 28 does guide the coupler through positions 1, 2, and 3, but mechanically it cannot get from position 2 to 3 without disconnecting the output crank between configurations.

To guard against this pitfall, a graphical solution should always be checked by a model or by a layout for the complete range of motion. For the same reason, some of the digital-computer programs include a displacement analysis of the mechanism found in the analytical design portion of the program.

ACKNOWLEDGMENT

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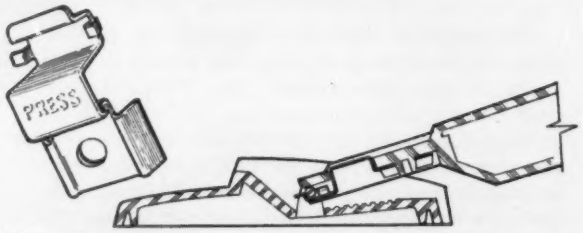
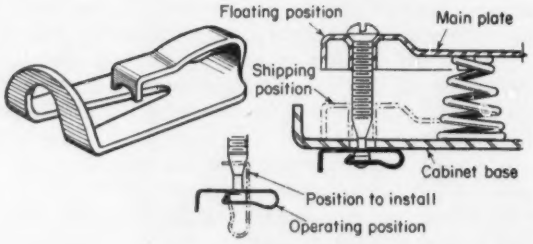
MULTIPLE-FUNCTION FASTENERS

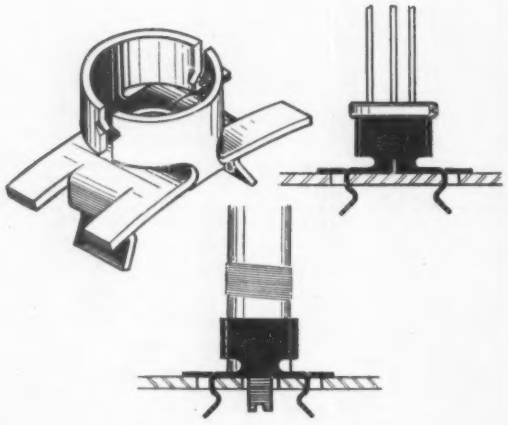
Fasteners shown here were developed to perform one or more functions in addition to the primary job of fastening. Made of heat-treated spring steel, they all incorporate some form of screw-locking impression or retaining device, eliminating the need for other secondary fastening elements such as nuts or lockwashers. Information and sketches, courtesy Tinnerman Products Inc.



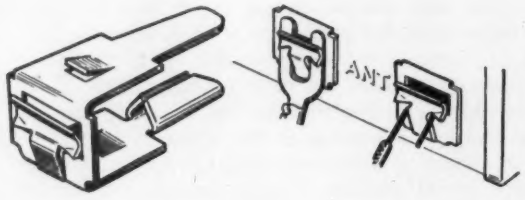
Speed clip retains plastic mop head to handle and also serves as a hinge. Design permits quick and easy separation of the two parts. Pressure on the clip at the point marked "PRESS" disengages the clip from the hinge pin which is permanently set in the mop head. The one-piece fastener is self-retaining and requires no added parts handling during assembly. The clip is simply centered on a locating stud in the handle and snapped into place. Spring legs expand beneath ridges within the handle cavity to hold clip permanently in position.



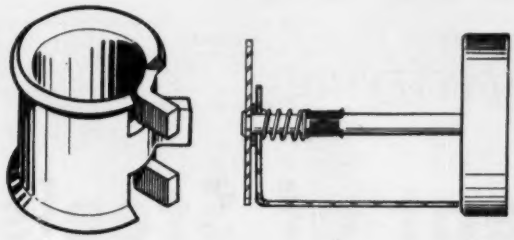
Toggle-type clip anchors main plate of automatic record player and permits adjustment of plate position for shipping and playing. Clip is used with a ball-point screw. To assemble clip, screw is turned all the way in and plate is manually forced down to shipping position. Clip is pushed on to protruding ball point and rotated to seat flat against outer surface of cabinet space. The plate then returns to the floating (playing) position with the screw held captive by the clip. For shipping, the screw is backed off, forcing the plate down into the secured position where it is locked firmly against the cabinet to prevent jostling and damage of components in transit.



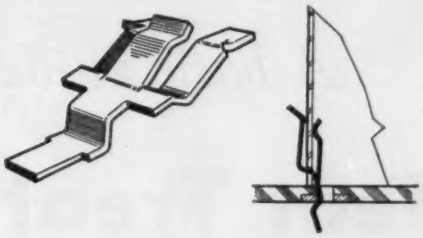
Originally designed as a coil-form retainer, this fastener is also well suited for use as a transistor clip. It is self-retained under spring tension that acts to cushion shocks. Retaining collar serves as a heat sink, drawing heat from all directions and transmitting it through the spring legs and tabs into the panel. Openings at both sides and bottom of the collar allow air to circulate, increasing heat dissipation. Four tiny barbs and compression of the collar retain the transistor in a firm grip.



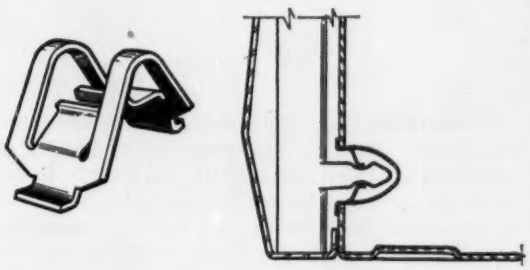
One-piece, self-retaining lead-in clip for television antenna serves as electrical conductor and provides for slide-type or solder connection on the inside, bare wire or spade terminal connection on the outside. Clip is pressed into square hole in panel. Anchor tabs snap over the underside of the panel to hold the clip firmly in place.



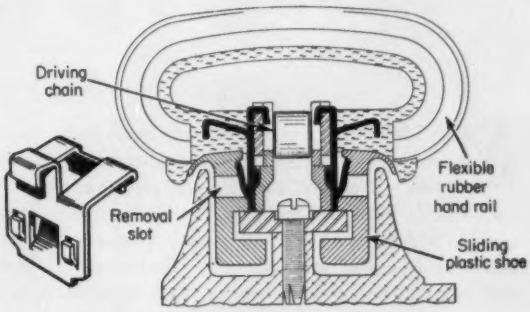
Self-retaining compression ring can be installed and positioned with a pair of standard pliers to provide adjustable tension of shaft-mounted springs. Developed for use in ribbon cylinders of an electric typewriter, it has flared ends, which double as a spring seat and a pilot for ease of assembly. This fastener can also be used to clamp small diameter hose or to retain removable assemblies on automobile bodies, dash and splasher panels, cabinets, electronic equipment, and toys.



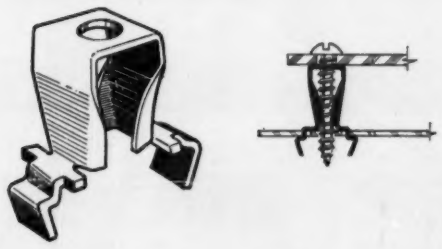
Speed clip was designed to anchor I. F. cans on printed circuit boards. The spring leg of each clip projects through the board, retaining the I. F. can under tension until the dip-soldering operation. Barbs bite into the can for positive grounding. The solder completes the ground connection from clip to circuit and secures the clip permanently to the circuit board. Removal of the can for inspection is accomplished by expanding the leg of the clip away from the can with a simple tool.



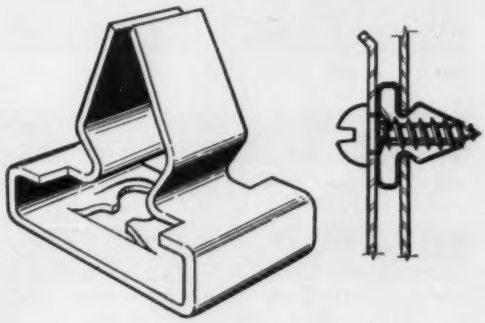
Spring-catch type clip is used to attach access doors and panels. Clip is mounted in prepared hole in base panel or chassis and stud on panel or access door is then pressed into place. There is no direct contact between the stud and the panel, eliminating chipping of painted or porcelained surfaces. Clip construction permits use of an inexpensive stamped latching stud or ball stud, and resists loosening effect of vibration.



Molded-in clips in flexible escalator hand rail fasten the rail to both the drive chain and a sliding plastic shoe. The clips hook on to the drive chain and are snapped down into the plastic shoes. The shoe locks the drive chain in place and a spring tab on the clip snaps into a cavity in the shoe, holding the assembly as though it were one solid piece. A removal slot is incorporated so that a screwdriver can be inserted to compress the locking tab for disassembly.



Self-retaining clip secures printed circuit board to chassis and serves as a spacer. It has bowed spring legs that snap into place and lock on underside of chassis. After the phenolic circuit board is positioned, the screws are inserted and driven home. To prevent cracking due to overtorquing of the screws, the clip has a broad flat head providing a substantial base at each fastening point. Long body of clip provides ½ in. clearance between board and chassis.



Combination fastener and spacer is used to assemble sheet-metal parts. Fastener is snapped into square hole in base member, part is positioned, and screw is driven. As screw passes through fastener, it expands the dart-shaped retaining legs, providing a firm locking grip on the base member. Part is held securely in place away from the surface of the base member.

A basic guide to specifying

Heat Treatment of Steels

Part 2—Steel Selection

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Waukesha, Wis.

MECHANICAL properties of steel parts may be controlled by various heat-treating methods. But without proper selection of the steel itself, heat treating can be ineffective. This article, which concludes the series, discusses criteria for steel selection and presents tabular comparison data on commonly used carbon and alloy steels.

Selection of a steel begins at the ingot stage, since the deoxidation method dictates the general end-use category for the material.

*Now with Lewis Research Center, NASA, Cleveland, Ohio.

Killed Steels: Thoroughly deoxidized or killed steels are characterized by a high degree of uniformity of composition and of mechanical properties. Killed steels are produced by adding aluminum or silicon to the poured ingot so that no reaction occurs between oxygen and carbon during solidification.

Semikilled Steels: Partial deoxidation of the ingot, permitting sufficient carbon monoxide to form during cooling to offset shrinkage from solidification, produces semikilled steels. These steels are used

Table 1—Relation of Diameter to As-Quenched Hardness*

AISI Type	Analysis (per cent) C	Mn	Si	Ni	Cr	Mo	Grain Size (McQuaid-Ehn)	Austenitizing Temperature (F)	Position on Bar†	Bar Diameter (in.) 0.50	1.0	2.0	4.0
										Oil-Quenched Hardness, Rockwell C			
1340	0.40	1.77	0.25	0.10	0.12	0.01	6-8	1525	S	58	57	39	32
									R/2	57	56	34	30
									C	57	50	32	26
3140	0.40	0.90	0.27	1.21	0.62	0.02	5-8	1525	S	57	55	46	34
									R/2	57	55	40	33.5
									C	57	55	40	33.5
4140	0.40	0.83	0.26	0.11	0.94	0.21	7-8	1550	S	57	55	49	36
									R/2	56	55	43	34.5
									C	55	50	38	34
4340	0.40	0.68	0.28	1.87	0.74	0.25	7-8	1475	S	58	57	56	53
									R/2	58	57	55	49
									C	56	56	54	47
4640	0.39	0.68	0.31	1.87	0.08	0.24	7-8	1475	S	57	54	39	30
									R/2	57	54	34	28
									C	56	47	32	26
5140	0.43	0.78	0.23	0.06	0.74	0.01	6-8	1550	S	57	53	46	35
									R/2	57	48	38	29
									C	56	45	35	30
8740	0.41	0.90	0.25	0.63	0.53	0.29	7-8	1525	S	57	56	52	42
									R/2	56	55	49	37
									C	55	54	45	36

*From Reference 2.
†S=surface; R/2=half radius; C=center.

Table 2—Effect of Mass on Mechanical Properties of Common Steels*

AISI Type	Diameter (in.)	Tensile Strength (1000 psi)	Yield Strength (1000 psi)	Elongation in 2 in. (per cent)	Area Reduction (per cent)	Hardness, Brinell (kg/sq mm)	Impact, Izod (lb-ft)
Oil Quenched and Tempered at 1000 F							
1340	0.5	142	132	18.8	55.2	285	50.0
	1.0	138	121	19.2	57.4	285	54.5
	2.0	121	94	21.2	60.7	248	73.0
	4.0	117	83	21.7	57.9	241	84.2
3140	0.5	151	141	17.4	54.5	302	48.2
	1.0	147	132	17.5	57.0	293	47.5
	2.0	130	103	19.7	60.7	269	64.5
	4.0	121	91	20.0	56.9	248	50.2
4140	0.5	172	161	15.4	55.7	341	43.5
	1.0	156	143	15.5	56.9	311	54.5
	2.0	140	116	17.5	59.5	285	66.7
	4.0	128	99	19.2	60.4	277	37.7
4340	0.5	182	169	13.7	45.0	363	37.5
	1.0	175	166	14.2	45.9	352	39.0
	2.0	170	160	16.0	54.8	341	53.0
	4.0	165	145	15.5	53.4	331	46.0
4640	0.5	161	147	17.1	55.7	321	46.7
	1.0	155	145	17.0	56.3	321	46.7
	2.0	132	105	19.2	58.2	269	64.0
	4.0	128	97	20.2	56.2	248	64.0
5140	0.5	147	132	17.8	57.1	302	45.5
	1.0	141	122	18.5	58.9	293	46.7
	2.0	128	101	19.7	59.1	255	66.1
	4.0	125	83	20.2	56.4	248	20.3
8740	0.5	179	165	13.5	47.4	352	34.0
	1.0	179	164	16.0	53.0	352	35.5
	2.0	171	154	15.7	52.8	331	40.5
	4.0	139	100	18.0	55.6	277	33.2
Oil Quenched and Tempered at 1100 F							
1340	0.5	127	118	21.0	57.9	255	83.7
	1.0	118	98	21.7	60.1	241	89.2
	2.0	109	82	24.7	64.3	217	95.2
	4.0	103	71	25.5	64.5	217	94.5
3140	0.5	138	126	20.0	59.2	277	87.0
	1.0	132	119	21.2	61.0	269	85.0
	2.0	123	96	21.5	63.3	248	89.5
	4.0	109	78	23.7	65.9	217	88.5
4140	0.5	158	149	18.1	59.4	321	98.0
	1.0	140	135	19.5	62.2	285	70.5
	2.0	128	103	21.7	65.0	262	94.0
	4.0	117	87	21.5	62.1	235	82.5
4340	0.5	166	163	17.1	57.0	331	66.5
	1.0	165	160	16.5	54.1	331	60.5
	2.0	147	130	19.0	60.4	293	75.5
	4.0	134	115	19.7	60.7	269	61.7
4640	0.5	148	143	19.2	55.3	293	98.7
	1.0	145	133	18.0	59.3	285	98.0
	2.0	119	94	22.2	63.1	235	81.5
	4.0	112	88	23.2	62.6	229	81.5
5140	0.5	131	113	20.2	61.4	269	86.3
	1.0	127	105	20.5	61.7	262	56.7
	2.0	118	89	22.0	63.2	241	86.9
	4.0	116	74	22.1	59.0	235	60.7
8740	0.5	154	140	17.4	55.1	311	58.5
	1.0	149	135	18.2	59.9	302	67.5
	2.0	143	123	18.5	62.0	277	77.7
	4.0	124	97	20.5	60.8	248	75.0
Oil Quenched and Tempered at 1200 F							
1340	0.5	119	109	22.1	59.5	241	89.7
	1.0	112	96	23.2	62.4	229	75.5
	2.0	106	80	25.5	66.2	217	90.5
	4.0	102	72	26.0	64.8	212	86.7
3140	0.5	128	117	21.7	62.6	255	72.5
	1.0	125	109	21.5	60.2	248	66.5
	2.0	115	85	23.5	66.7	229	92.0
	4.0	108	79	24.2	65.6	217	91.0
4140	0.5	137	120	19.9	62.3	277	73.6
	1.0	133	123	21.0	65.0	269	84.5
	2.0	122	98	23.2	65.5	241	91.2
	4.0	113	94	23.2	64.9	229	90.7
4340	0.5	145	136	20.0	59.3	285	67.5
	1.0	139	128	20.0	59.7	277	72.7
	2.0	135	121	20.5	62.5	269	86.2
	4.0	124	106	21.7	63.0	255	91.0
4640	0.5	129	115	21.7	60.6	262	71.7
	1.0	122	110	21.5	60.3	248	75.5
	2.0	115	94	23.2	65.2	229	88.2
	4.0	106	86	24.7	64.4	217	88.2
5140	0.5	120	102	22.2	63.4	241	74.5
	1.0	117	90	22.5	63.5	235	80.1
	2.0	110	82	24.5	67.1	223	100.1
	4.0	106	68	24.6	63.1	217	46.1
8740	0.5	140	127	19.9	60.7	285	70.5
	1.0	138	122	20.0	60.7	285	75.7
	2.0	127	106	21.5	65.4	255	89.7
	4.0	116	88	22.7	63.9	229	85.2

*Properties listed are single-heat results. Data from Reference 2.

where the greater uniformity of killed steels is not required.

Rimmed and Capped Steels: Incompletely deoxidized (rimmed) steels are characterized by a purer-than-poured rim section and a less-pure core. Because of their superior surface finish, rimmed steels are used for press-fabrication applications.

Capped and rimmed steels are similar, except that the rimming action of capped steels is curtailed shortly after the mold is filled. Capped steels have surfaces comparable to rimmed steels and uniformity similar to semikilled steels.

Selection Criteria

Mechanical properties of steels are related to microstructure and depend upon chemical composition,

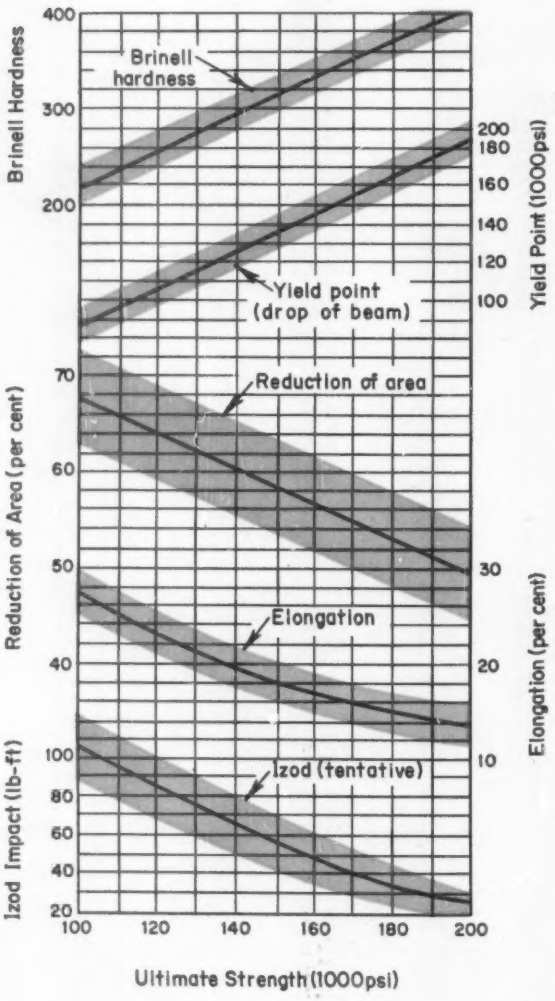

Fig. 1—Mechanical properties of quenched-and-tempered low-alloy (to about 2.0 per cent) steels with 0.30 to 0.50 per cent carbon content.[1]

Table 3—Carbon-Steel Characteristics

SAE Type	Remarks
1006, 1008, 1009, 1012, 1015	Available either as killed or rimmed steels. Killed steels, because of nonaging characteristics, are preferred for forged parts. Excellent for press and cold-heading applications. Steels having less than 15 per cent carbon content are subject to brittleness in cold working. A stress-relief anneal over 1100 F may also induce brittleness.
1016, 1017, 1018, 1019, 1020, 1021, 1022, 1023, 1024, 1025, 1026, 1027, 1030	Usually produced as killed steels for carburized applications, but also available as semikilled and rimmed. Forgings of the lower-carbon steels have good machinability in the as-forged condition.
1030, 1033, 1035, 1036, 1037, 1038, 1039, 1040, 1041, 1042, 1043, 1045, 1046, 1048, 1049, 1050, 1052	Usually produced as killed steels. This medium-carbon group offers high strength and hardness properties when processed with the quench-and-temper treatment.
1055, 1060, 1064, 1065, 1070, 1074, 1078, 1080, 1084, 1085, 1086, 1090, 1095	Used where the high carbon content is required for hardness of cutting edges or for spring applications. These killed steels are usually processed with the quench-and-temper treatment.
1111, 1112, 1113	Rimmed and capped steels of this group are used for parts that require high machinability. Although they have high strength in the cold-drawn condition, these steels tend toward cold shortness. When optimum response to heat treatment is required, killed open hearth or electric steels are recommended.
1108, 1109, 1115, 1117, 1118, 1119, 1120, 1126	Normally used for parts requiring carburization. These steels are recommended for applications that require good machinability and uniform response to heat treatment.
1132, 1137, 1138, 1140, 1141, 1144, 1145, 1146, 1151	Used in the quenched-and-tempered condition for parts that require a considerable amount of machining. Killed steels are used where uniformity of response to heat treatment is required.

Table 4—Alloy-Steel Characteristics

SAE Low-Hardenability Steels	SAE Medium-Hardenability Steels	SAE High-Hardenability Steels	Remarks
1330, 1335, 4037, 4042, 4130, 5130, 5132, 8630	3135, 4137, 5135, 8637, 94B30	.....	Heat treatment of these steels usually involves water quenching for moderate sections and oil quenching for small-section parts. Typical applications include connecting rods, steering arms and knuckles, axle shafts, bolts, studs, and screws.
1340, 4047, 5140	3140, 4043, 4140, 4640, 8640, 8642, 8740, 50B40, 97B40	4340, 9840	Used for medium and large-sized parts requiring toughness and high strength. Low and medium-hardenability steels are used for steering knuckles, axles, and propeller shafts. High-hardenability steels are used for larger axles and shafts and for large aircraft parts. These are normally oil-quenched steels. However, some large parts of low and medium-hardenability steels may be water quenched under properly controlled conditions.
5046, 50B44, 5145, 50B46	4145, 5147, 5150, 8645, 8650, 81B45	4150	Primarily used for gears and similar parts requiring fairly high hardness combined with strength and toughness. These are oil-quenched steels normally requiring 90 per cent martensitic structure in the as-quenched condition.
.....	50B50, 5150, 50B60, 5155, 51B60, 6150, 8650, 9245, 9255, 9260	8655, 8660, 9262	Primarily used for springs and hand tools. Hardenability depends on thickness of section and on quenching process.
50100	51100, 52100	.....	Used for races, balls, and rollers of antifriction bearings, and for similar parts that require hardness and wear resistance.

grain size, and type of heat treatment. Steels with similar carbon content will have similar mechanical properties when quenched and tempered to the same hardness, provided that a 100 per cent martensitic structure is formed at the center of the part. Thus, a ⅜-in. diam section will possess practically identical properties regardless of whether it is AISI 1040, 4140, 3140, or 4340, since critical cooling rates for maximum center hardness are similar, Fig. 1.

Mass Effect: As section size increases, the difference in cooling rates between center and surface also increases, and higher-alloyed materials are required to obtain depth hardening, Table 1.

Mechanical properties of quenched-and-tempered sections are also affected by mass, Table 2. Values shown are representative of a specific heat and can be expected to vary somewhat, depending upon chemistry, grain size, and other related factors.

Slack-Quenched Structures: The specification of a minimum percentage of martensite indicates that the center area of a section can have a slack-quenched structure; that is, the center will not be

Table 5—Physical Properties of Steels Based on Section Size and Quenching Medium*

Yield Strength (1000 psi)	Hardness at Critical Section, Rockwell C† After Temper	Hardness at Critical Section, Rockwell C† After Quench	Bar Diameter (in.) — Location of Critical Section — To 0.5 (Center)	0.5–1.0 (Center)	1.0–1.5 (½ Radius)	1.5–2.0 (½ Radius)	2.0–2.5 (¾ Radius)	2.5–3.0 (¾ Radius)	3.0–3.5 (¾ Radius)
For Highly Stressed Parts—Oil Quench									
90–125	23–30	42	1330H, 5132H, 4130H						
125–150	30–36	44	1335H, 5135H	3140H, 8740H, 4135H, 50B40 8640H	4137H	4142H 81B45		9840	4337H 9850 86B45
150–170	36–41	48	1340H, 4135H, 3140H, 5140H, 50B40, 4047H, 8637H	4137H, 8645H, 8642H, 8742H	4140H TS4140		4145H 9840	4147H 4337H 4147 81B45 86B45	4340
170–185	41–46	51	4063H, 8640H, 9260H, 4140H, 8642H, TS4140, 8740H, 50B44, 5145H, 8742H, 50B50, 5150H	5147H, 9262H, 5160H, 50B50, 6150H	4142H 8655H 4145H 50B60 4337H 81B45 8650H	8660H 51B60	4147H 4340H 81B45 86B45	4150H 9850 TS4150	
185+	46+	55	8655H, TS4150, 4150H, 50B60, 5160H, 9262H		8660H				
For Highly Stressed Parts—Water Quench‡									
90–125	23–30	42		1330H, 5132H, 4130H, 8630H 5130H					
125–150	30–36	44	1330H, 5132H, 4130H, 8630H 5130H, TS14B35	5132H			1340H 8637H 3140H 50B40	4135H	4137H
For Moderately Stressed Parts—Oil Quench									
90–125	23–30	42	1330H, 5132H, 4130H	8637H	3140H 8740H	4140H TS4140			
125–150	30–36	44	1335H, 4042H, 5135H	3140H, 8640H 4135H, 8740H	4137H 8615H 6150H 8742H 8642H		4142H	4145H	4337H 9850
150–170	36–41	48	1340H, 4047H, 8637H, 4135H, 3140H, 5140H, 50B40	4137H, 8645H 4140H, 8742H 5150H, 8642H TS4140	4142H 50B50 5147H		4145H 8655H 9840	4147H 4337H 81B45	4340H
170–185	41–46	51	4063H, 5150H, 8742H, 4140H, 8640H, 9260H, 8642H, TS4140, 5145H, 8740H, 50B44	4142H, 6150H, 4337H, 5147H, 50B50	4145H 9260H 8650H 50B60 8655H 81B45		4147H 4340H 8660H 51B60 81B45 86B45	4150H 9850 TS4150	
185+	46+	55	8655H, 9262H, 4150H, TS4150 5160H	50B60	8660H				
For Moderately Stressed Parts—Water Quench‡									
90–125	23–30	42	1040	1330H, 5132H, 4037H, 8630H, 4130H, 5130H, TS14B35			1340H 4135H 8637H		3140H 8740H 8640H
125–150	30–36	44	1330H, 1036 1045, 4130H, 8630H		1335H 5135H		1340H 3140H 5145H 5140H 8637H	4135H 8640H 5150H 8740H	4137H 8645H 4140H 8742H 6150H TS4140 8642H 50B40
150–170	36–41	48	1335H, 5135H, 4037H, TS14B35	4042H, 50B40	1340H 4135H 5140H 8637H 50B40		4137H 8640H 8740H 5145H 50B40	4140H 6150H TS4140 8645H 50B44 8742H	5147H 9262H 50B50

*From Reference 4.
†Steel selection for highly stressed parts is based on quenching to 80 per cent martensite at the critical section; for moderately stressed parts, 50 per cent martensite.
‡Steels having over 0.33 per cent carbon are susceptible to quench cracking during a water quench. Prototype testing is recommended.

completely hardened.

Mechanical properties of an incompletely hardened steel are inferior to those of a fully hardened steel after tempering both at similar temperatures. The degree of impairment of the properties depends upon initial hardness. A small amount of a nonmartensitic structure does not significantly affect the room-temperature tensile or impact properties of a material tempered to a low hardness level. However, a like amount of a nonmartensitic structure may result in a marked loss of toughness if the section is tempered to a high hardness level. For this reason, a steel that exhibits a slack-quenched structure near its center is normally specified only for low to moderately stressed parts.

Normally, a slack-quenched structure has no effect on the hardness-to-tensile strength relationship since this ratio is not structure-sensitive. However, yield point, ductility, and toughness are structure-sensitive, Fig. 2, and these properties decrease as percentage of nonmartensitic product increases.

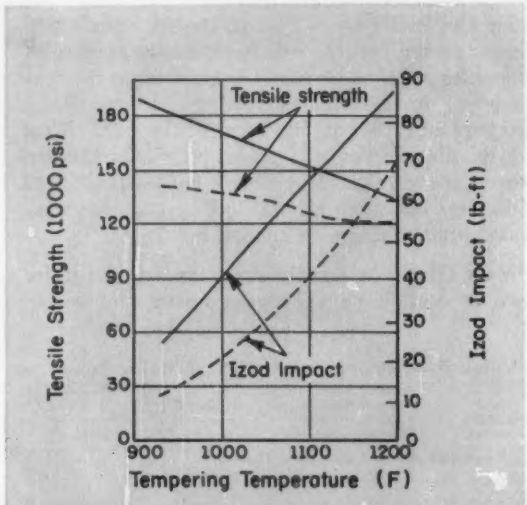

Fig. 2—Comparison of slack-quenched properties (dash lines—3.0-in. diam bar) with completely hardened properties (solid lines—5/16-in. diam bar) of the same low-alloy steel.[8]

Comparison Studies: As an aid to the selection of

Table 6—Properties of Quenched and Tempered Steels

AISI Type	Quench Temperature, Oil (F)	Tensile Strength (1000 psi)	Yield Strength (1000 psi)	Area Reduction (per cent)	Elongation (per cent)	Hardness, Brinell	Maximum Section (in.)
Tempered at 800 F							
1340	1550	180	168	51	14	375	1.25
2340	1425	180	167	50	15	375	1.00
3140	1500	187	170	51	13	388	1.40
4042	1500	185	168	50	16	375	0.75
4140	1500	180	165	49	13	375	2.00
4340	1525	210	200	45	11	429	4.00
4640	1500	182	168	50	12	375	1.10
5140	1500	190	173	50	14	375	1.00
8640	1525	200	188	45	12	415	1.40
4150	1500	218	200	45	12	444	3.10
5150	1500	210	193	46	13	415	1.20
6150	1550	210	195	44	11	415	1.60
8650	1500	210	197	42	11	429	2.00
9850	1500	215	195	44	12	415	3.50
Tempered at 1000 F							
1340	1550	140	122	58	18	293	1.25
2340	1425	140	123	58	20	302	1.00
3140	1500	142	130	60	17	302	1.40
4042	1500	140	125	59	19	293	0.75
4140	1500	138	122	57	18	285	2.00
4340	1525	172	160	52	13	363	4.00
4640	1500	140	125	58	19	285	1.10
5140	1500	140	125	58	17	293	1.00
8640	1525	165	148	53	15	341	1.40
4150	1500	173	160	53	15	363	3.10
5150	1500	165	150	54	15	311	1.20
6150	1550	170	155	50	14	352	1.60
8650	1500	170	156	49	12	341	2.00
9850	1500	178	160	50	14	352	3.50
Tempered at 1200 F							
1340	1550	115	90	70	22	248	1.25
2340	1425	110	95	65	25	269	1.00
3140	1500	114	100	66	24	241	1.40
4042	1500	112	98	65	27	229	0.75
4140	1500	110	95	63	23	229	2.00
4340	1525	140	123	60	18	277	4.00
4640	1500	110	92	64	25	241	1.10
5140	1500	110	98	65	25	229	1.00
8640	1525	130	113	60	20	277	1.40
4150	1500	138	123	61	19	285	3.10
5150	1500	130	117	60	20	262	1.20
6150	1550	138	123	58	18	277	1.60
8650	1500	140	125	58	20	262	2.00
9850	1500	140	121	58	17	277	3.50

steels, various types can be grouped according to general characteristics. For example, carbon steels can be classified in accordance with carbon content and free-machining characteristics, Table 3. Similarly, alloy steels can be classified in accordance with carbon content and hardenability characteristics, Table 4, yield strength and section size, Table 5, or tempering levels, Table 6.

When an alloy steel is chosen for an application, economic justification can only be made on the basis that the material will be heat treated to obtain its maximum possible combination of strength and ductility. All alloy steels are thoroughly deoxidized to obtain uniformity of mechanical properties.

Design Factors

In a liquid-quench operation, the cooling-rate differential between the center of a section and its surface causes internal stress. This stress is often evident in the form of warpage, particularly in thin sections. In severe cases, high stress concentrations produced during quenching cause part failure, indicating that the stress level has exceeded the ultimate strength of the metal.

Design recommendations for minimizing internal stresses are: 1. Reduce the thermal gradient within a section to a minimum. 2. Avoid configurations that permit localized areas to become stress raisers.

Typical stress raisers are sharp angles, sharp corners, and blind holes. Drastic changes of section size must be eliminated to reduce high thermal gradients.

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1. W. G. Patton—"Mechanical Properties of NE, SAE, and Other Hardened Steels," *Metal Progress*, May, 1943.
2. *Modern Steels and Their Properties*, Bethlehem Steel Co., Bethlehem, Pa., 1955.
3. R. S. Archer, J. Z. Briggs, and C. M. Loeb Jr.—*Molybdenum Steels and Irons*, Climax Molybdenum Co., New York, 1948, pp. 66-71.
4. *Practical Data for Metallurgists*, Steel and Tube Div., Timken Roller Bearing Co., Canton, Ohio, September, 1959, pp. 42-46.

Tips and Techniques

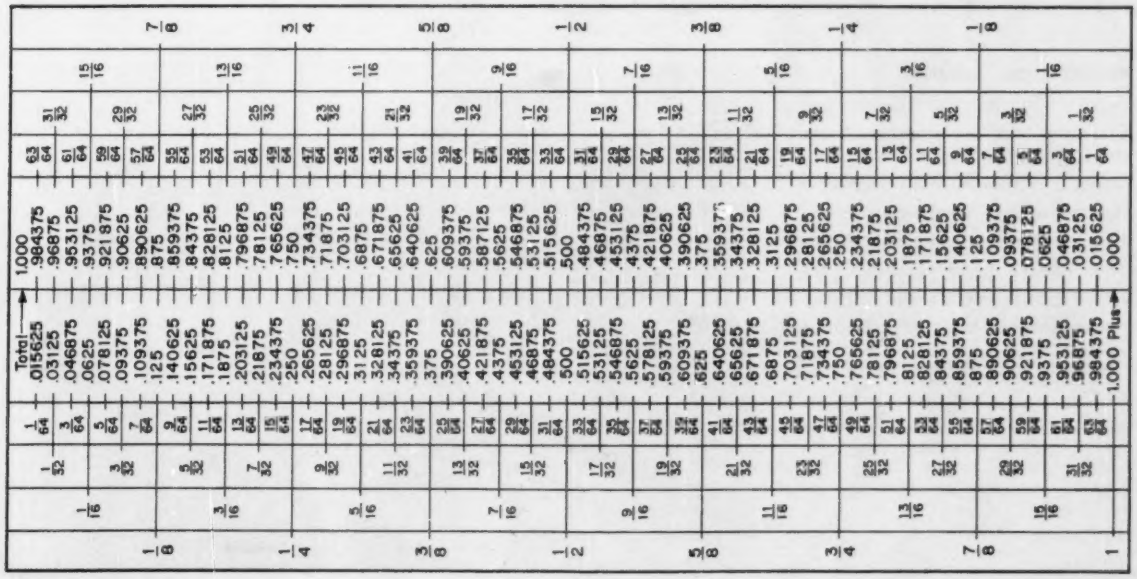
Adding and Subtracting Fractions

A simple slide rule such as the one shown allows rapid addition and subtraction of fractions, and also serves as a handy conversion chart. First, cut the two sections apart along the center line. Then, for addition, simply line up the fractions to be added, and read the answer indicated by the arrow. For subtraction, set the "Total" arrow opposite the minuend. The answer can then be read directly opposite the subtrahend.—OTTO K. GRADE, *Senior Methods Engineer, Machlett Laboratories Inc., Springdale, Conn.*

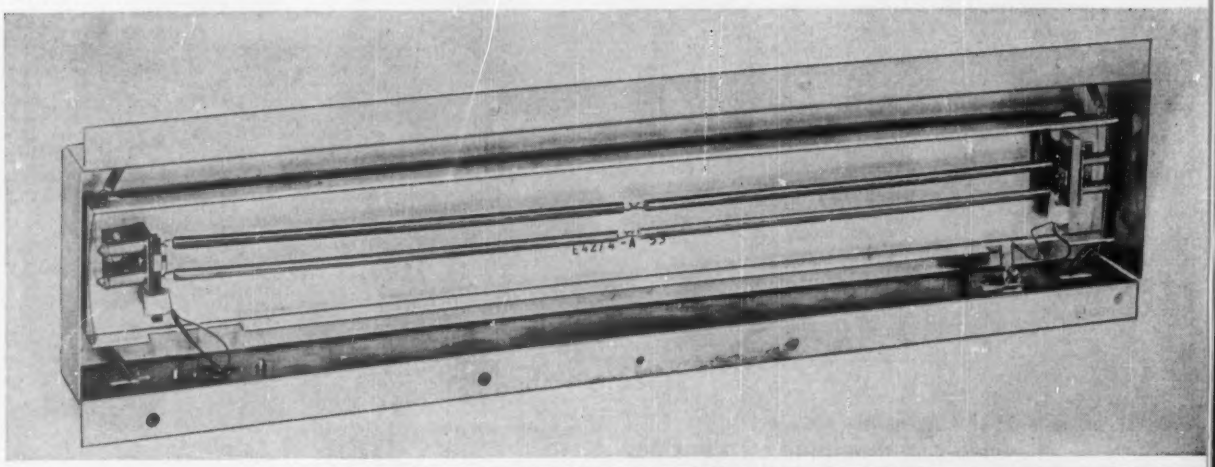
Cosines of Small Angles

To find the cosine of an angle which is too small for accurate reading on a slide rule, use the identity $\cos x = \sin x / \tan x$. Thus, to find the cosine of 6.4 deg, set the hairline of the slide rule over the sine of 6.4 deg, and bring 6.4 on the T scale under the hairline. The required cosine, 0.994, can then be read on the D scale, opposite the C-scale index.—JESSE ROTH, *New York, N. Y.*

Do you have a helpful tip or technique for our other readers? You'll receive ten dollars or more for each published contribution. Send a short description plus drawings, tables, or photos to: Tips and Techniques Editor, MACHINE DESIGN, *Penton Bldg., Cleveland 13, O.*

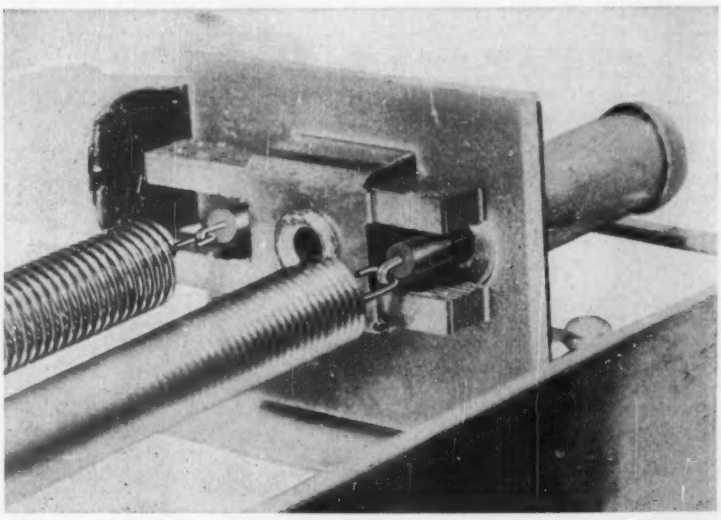


Coiled-Spring Delay Adds



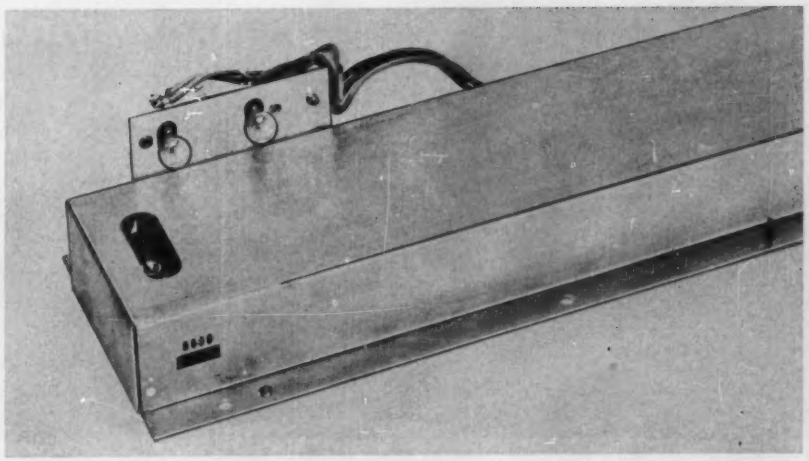
DELAY IN TRANSMISSION of high-fidelity phonograph signals is mechanically produced with carefully wound springs. Transducers at one end of the spring system convert the input to rotary motion which they apply to the ends of the springs. Instead of one long spring, each delay channel consists of two matched springs wound in opposite directions and hooked together to make one unit. Slight rotations due to axial vibrations are cancelled by the opposite sense of the two springs. Highly compliant springs reflect the input signal several times before delay. Delay characteristics of the springs are carefully chosen to simulate concert-hall conditions: Too long a delay (more than 50 msec) produces an objectionable echo. Too little delay gives an effect much like singing in the bathtub—that is, the feeling of spaciousness is lost. The springs chosen have built-in delay times of 37 and 29 msec respectively. The slight variation in delay time smooths out what might otherwise be an unpleasant modulation of the input signal.

TRANSDUCERS CONSIST of cylindrical magnets mounted between the arms of a U-shaped magnetic core. Field winding receives input signal and induces rotary motion in the transducers by change in the magnetic field. Similar units at the other end of the spring convert the rotary motion into an electrical signal which goes to the reverberation amplifier unit.

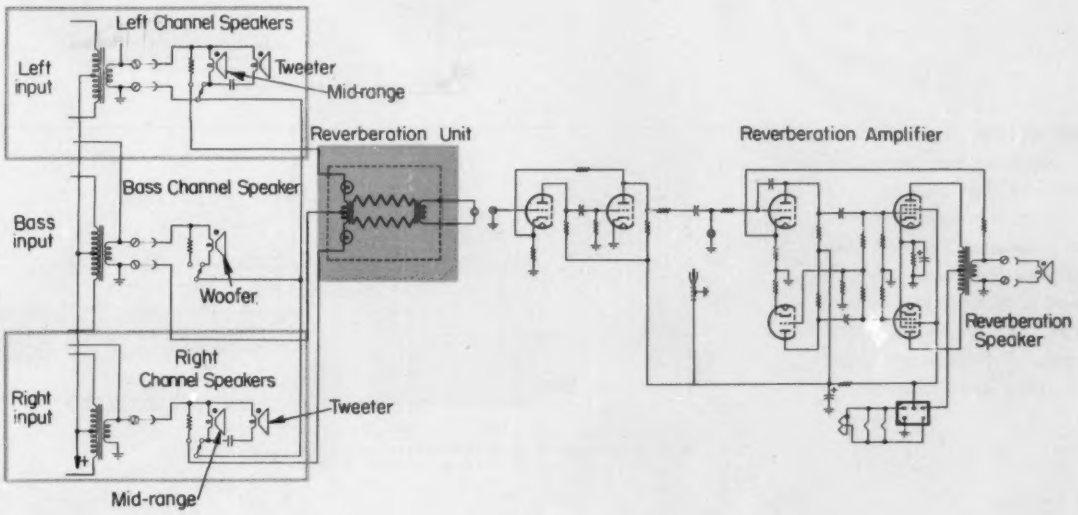


Reverberation to Hi Fi

LAMPS LIMIT reverberation response in high-amplitude signals. At low input levels the lamps remain cool and virtually all of the input is passed to the reverberation unit. But at high levels, the lamp is lighted and the hot filament acts as a resistor to limit the amount of input that reaches the transducers.



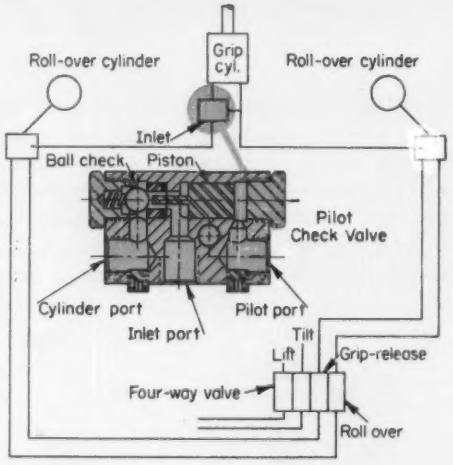
REVERBERATION INPUT MIXES signals from midfrequency and high-frequency stereo units. Low-frequency signals are not necessary in the stereo or reverberation units; designers of the system found the impression of space comes from reverberation and delay of frequencies above 200 cps. Separate speakers are used because the developers feel acoustical mixing is more realistic to the listener than electronic mixing. Mechanical spring delay system was developed by Hammond Organ Inc. Design of the high-fidelity stereo system in which it is used is by Motorola Inc., Chicago, Ill.



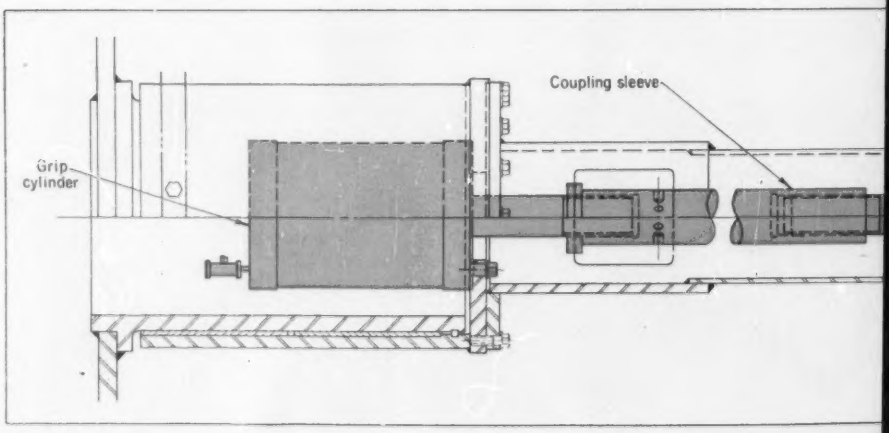
Piston-Chain Set Rotates

HYDRAULIC PISTONS DRIVE a chain that rotates a billet grab 90 degrees either way from center position. Chain is bolted at

GRAB REPLACES FORK on most fork-lift trucks. Control is a single four-way valve that operates truck lift and tilt mechanisms as well as the grab and roll cylinders. Ball check maintains grip cylinder pressure under load even when grip valve is centered. Release pressure moves a small piston in the check-valve body to push the ball check out of its seat, thus permitting fluid to escape from the grip cylinder.

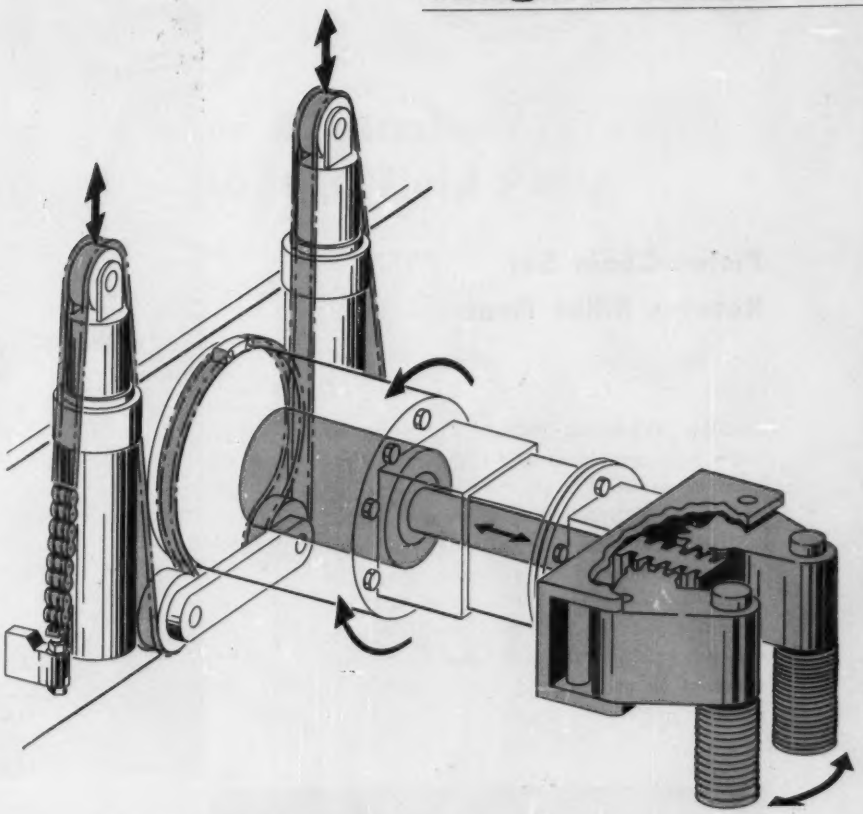


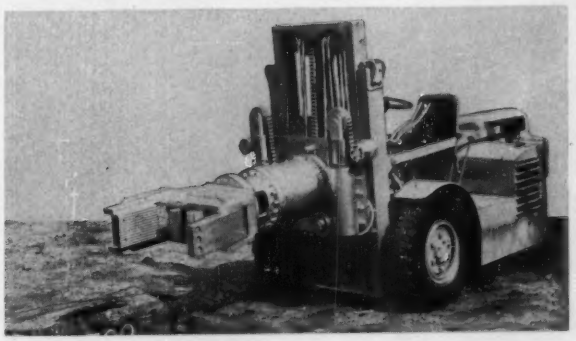
GRIP ACTION is provided by a rack-and-gear mechanism similar to that seen on some of the high-powered manipulators in atomic-energy laboratories. Grip arms have tapered holes to receive various types of fingers. Tapered shanks of fingers are keyed into place after insertion.



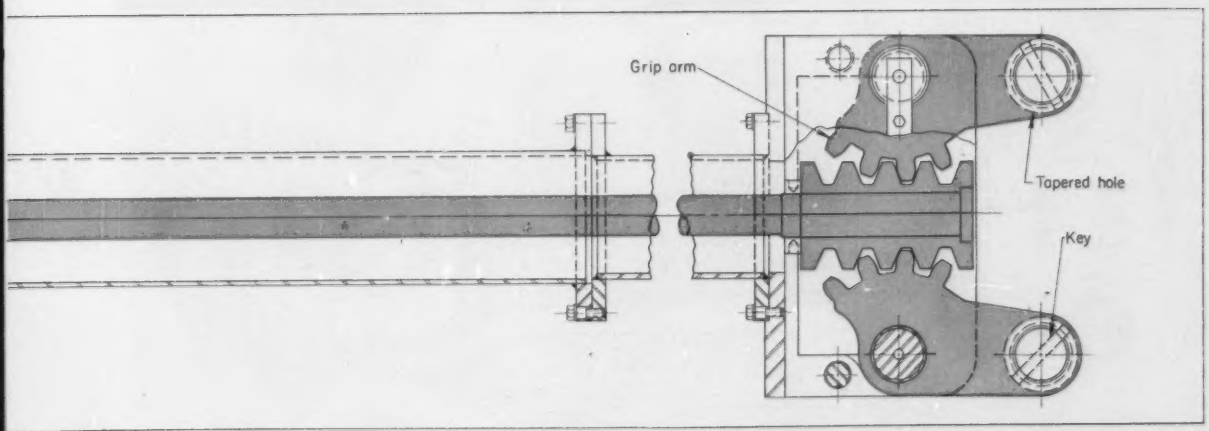
Billet Grab

midpoint to the billet-grab arm. This is a more positive coupling than a sprocket wheel would make, and eliminates most of the backlash in the movement. Idler pulleys are positioned to hold the chain in contact with the arm for more than 180 degrees, thus assuring positive torque control at the 90-degree position of the arm on either side.



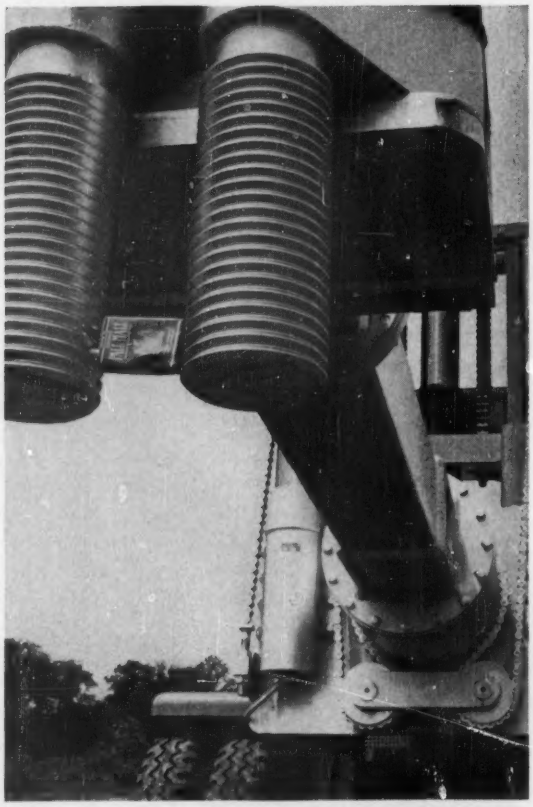


BILLET GRAB for handling steel billets in forging operations can be used in a wide variety of industries calling for precise manipulation of heavy pieces. It was reported by Samuel Kassouf, Chief Engineer of Morrison Co., Cleveland, the developer.

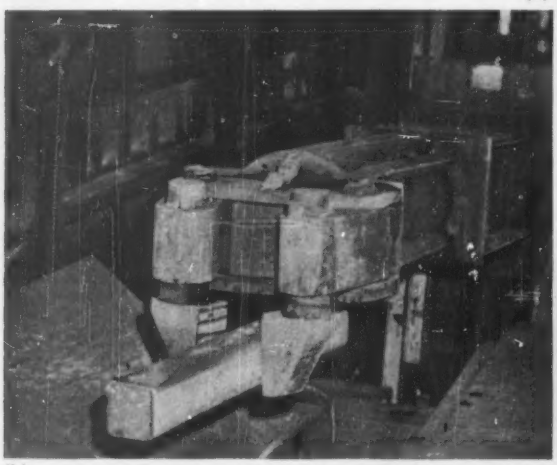


Piston-Chain Set Rotates Billet Grab

FINGERS AVAILABLE INCLUDE: a. Universal finger with grip ridges. This finger can be rotated as it wears to use the total surface of the ridges. b. Standard wedge-shaped finger. c. Thumb-and-finger integral with grip arms. d. Tongs connected to grip arms through a link. They are used to pick up crucibles or other flanged vessels. Tong hinges are on the grab arm near the grip cylinder. Links are designed to give desired motion relative to grip-arm motion.



(a)



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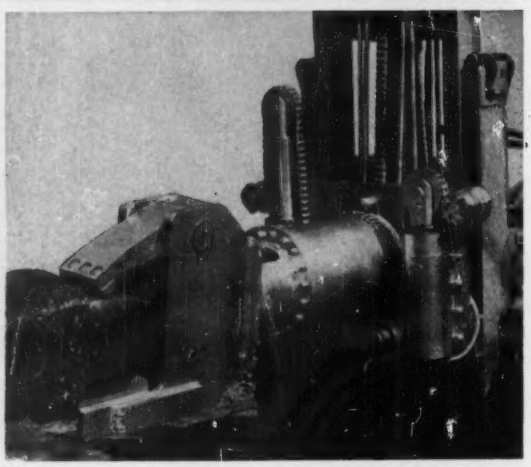

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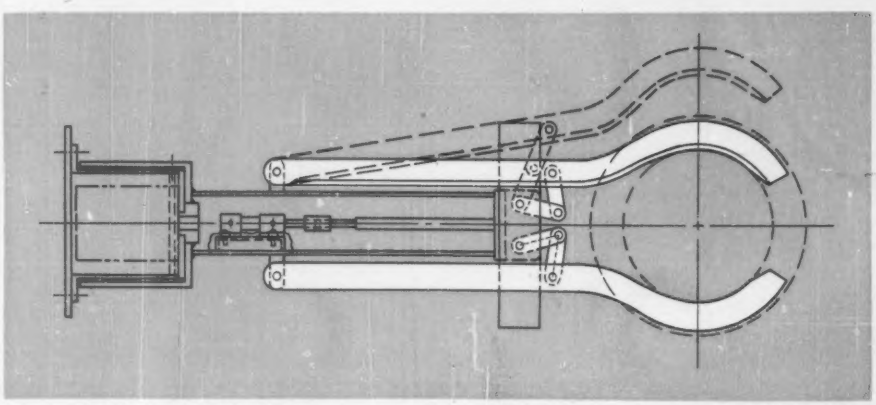
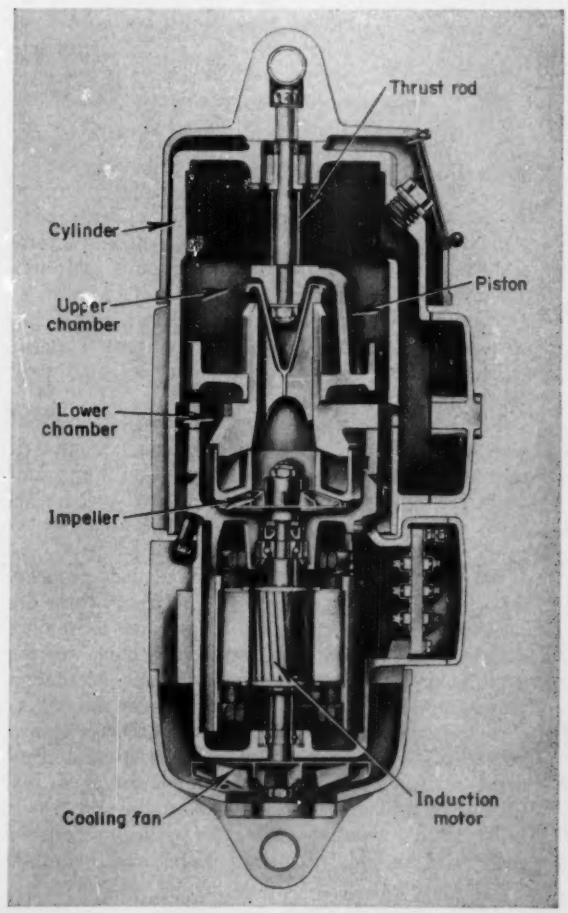


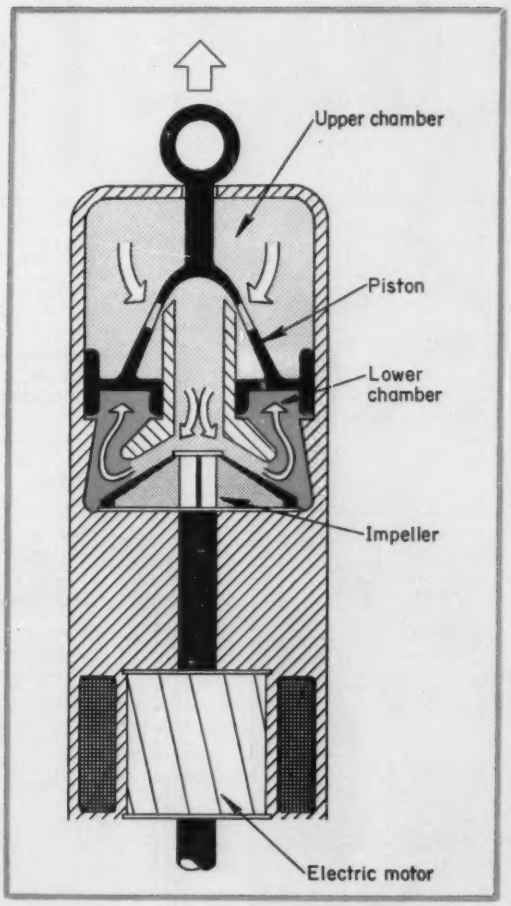
(d)

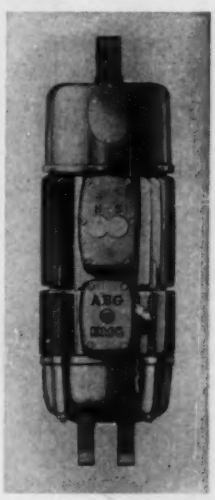
Hydraulic Linear Actuator Eliminates Lines and Valves With Built-in Fluid Pump

ONLY WIRE LEADS are attached to a short-stroke single-acting hydraulic cylinder. Fluid pump and its motor are contained within the cylinder housing. Fluid flows from the upper chamber through the center portion of the piston, past the pump, into the lower chamber to drive the piston.

VALVE CONTROLS FLUID FLOW to maintain required speed of stroke and recovery. It can be adjusted while the cylinder is operating, says the developer.







Hydraulic cylinder with built-in fluid pump is a development of Elektro-Mechanik GmbH, Wendenerhuette, Germany.

Basic operating relationships and recommended design practices for

Air-Oil Shock Absorbers

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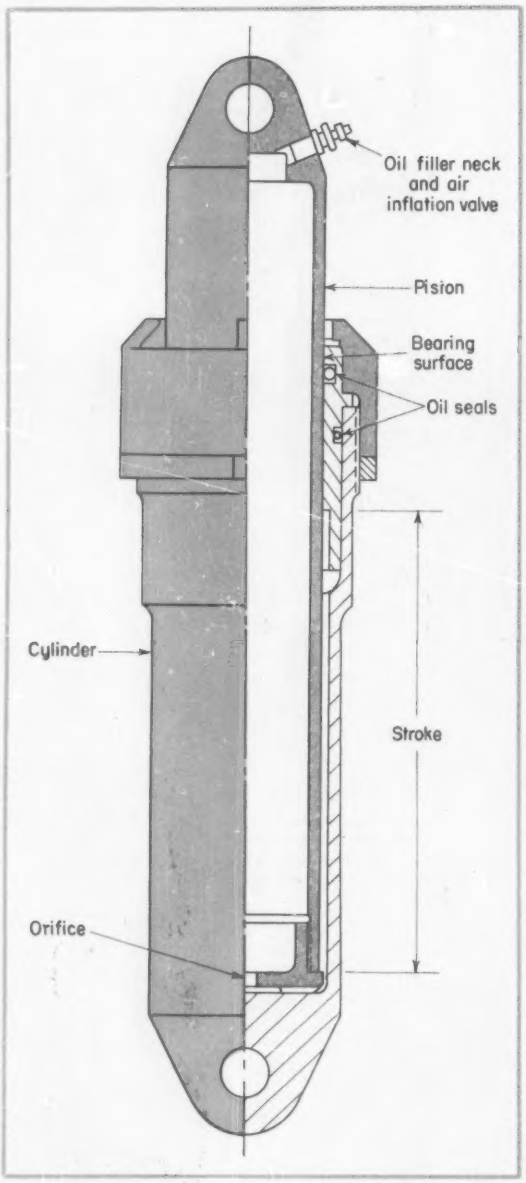


Fig. 1—Simple air-oil shock absorber shown empty and in fully compressed position.

AIR-OIL shock absorbers have a number of inherent advantages as impact-energy-absorption devices. Sometimes called oleopneumatic shock struts or, simply, oleo struts, they have been widely used as the shock-absorbing elements in aircraft landing gears. In contrast to pure hydraulic dampers, they can support a static load, as well as absorb dynamic forces. As compared to liquid-spring struts, air-oil struts have less stringent surface-finish requirements and they usually permit a longer operating stroke.

The main disadvantage of the simple air-oil strut, which has air and oil in direct contact, is that it cannot be operated horizontally. For horizontal operation, the air and oil must be completely separated. Various special configurations have been developed for this purpose.[1]

Basic relationships and recommended practices for the design of simple air-oil shock absorbers are presented in this article. Concepts and techniques discussed here are of primary importance in the preliminary stage of design where basic design parameters and dimensions must be established.

A typical simple air-oil shock absorber is shown schematically in Fig. 1. It consists of a hollow piston with an orifice at the lower end and an oil-filler neck and air-inflation valve at the top; a cylinder with a bearing surface for sliding action; oil seals; and suitable quantities of air and hydraulic

[1]References are tabulated at end of article.

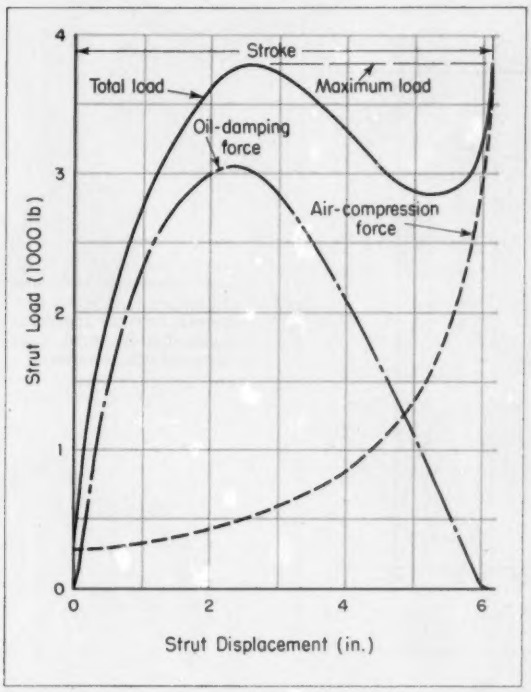
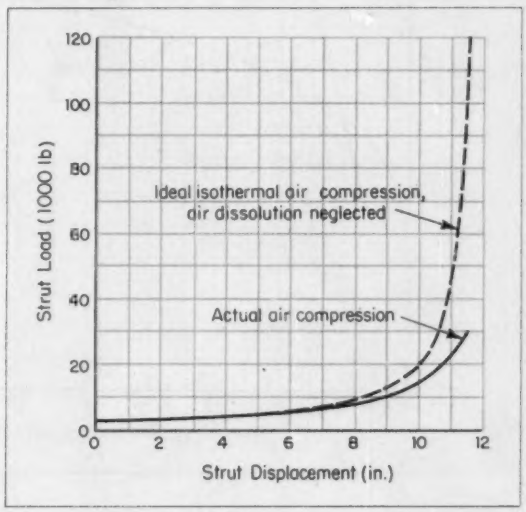


Fig. 2—Typical load-displacement curves for a simple air-oil shock absorber in a drop test. Strut displacement is measured from fully extended position.

Fig. 3—Typical load-displacement curve for a simple air-oil shock absorber under static loading, showing effect of air dissolved in oil. Strut displacement is measured from fully extended position.



oil. Operation of the air-oil shock absorber depends on the damping effect of oil as it is squeezed through the orifice and the spring effect of air as it is compressed.

In a simple strut of type shown in Fig. 1, the air and the oil are in intimate contact under pressure. Under static or slowly applied loading, a secondary effect is produced in which some of the air is dissolved within the oil. This secondary effect reduces the volume of free air in the system and, thus, decreases the static load-carrying capacity of the strut at a given operating position.

Determination of Forces

The total strut load under dynamic conditions is equal to the sum of the oil-damping force, the viscous piston drag force, and the air-spring force (See Nomenclature):

$$P = \frac{\pi^3 D^6 \rho}{18{,}432\, C_d^2 A_o^2} v^2 + \frac{3}{4} \pi \mu h \left(\frac{D}{c} \right)^3 v + P_{fc} \left(\frac{V_{fc}}{V_{fc} - \frac{\pi}{4} D^2 x} \right)^n \qquad (1)$$

Typical plots of oil-damping force, air-spring force, and total load for an aircraft-landing-gear strut during a drop test are shown in Fig. 2.

Experience under dynamic conditions has shown that discharge coefficient C_d varies from 0.60 to 0.90 and air-compression exponent n from 1.06 to 1.30. In most designs, viscous drag is small compared to oil-damping force.

Under static conditions, there are no oil-damping and piston-drag forces. Furthermore, the effect

Nomenclature

A_o = Total orifice flow area, sq. in.
C = Material factor, psi
$= S_w/N$
C_d = Orifice discharge coefficient
c = Radial clearance between piston and cylinder, in.
D = Piston outside diameter, in.
g = Gravitational acceleration, 32.2 ft per sec per sec
H_o = Height of oil above bottom of orifice in fully-extended strut position, in.
h = Piston length, in.
K = Saturation coefficient of air dissolved in oil, sq in. per lb
L_N = Net strut length, in.
L_{No} = Net strut length for zero stroke, in.
N = Dynamic-load factor
n = Air-compression exponent
P = Total strut load, lb
P_{max} = Maximum dynamic value of total strut load, lb
p = Air pressure in strut, psi
p_a = Atmospheric pressure, psi
S_w = Working stress or design allowable stress, psi
s = Stroke, in.
T = Thickness of orifice plate, in.
t = Piston wall thickness, in.
V = Free air volume in strut, cu in.
V_o = Oil volume in strut, cu in.
v = Strut closure velocity, ft per sec
x = Strut position or displacement measured from fully extended position, in.
ΔH = Drop in total height of oil from fully compressed to fully extended strut position, in.
η = Strut efficiency, (Equation 4)
μ = Absolute viscosity of oil, lb-sec per sq ft
ρ = Mass density of oil, slugs per cu ft

Subscripts
fc = Fully-compressed strut position
fe = Fully-extended strut position
s = Normal static strut position

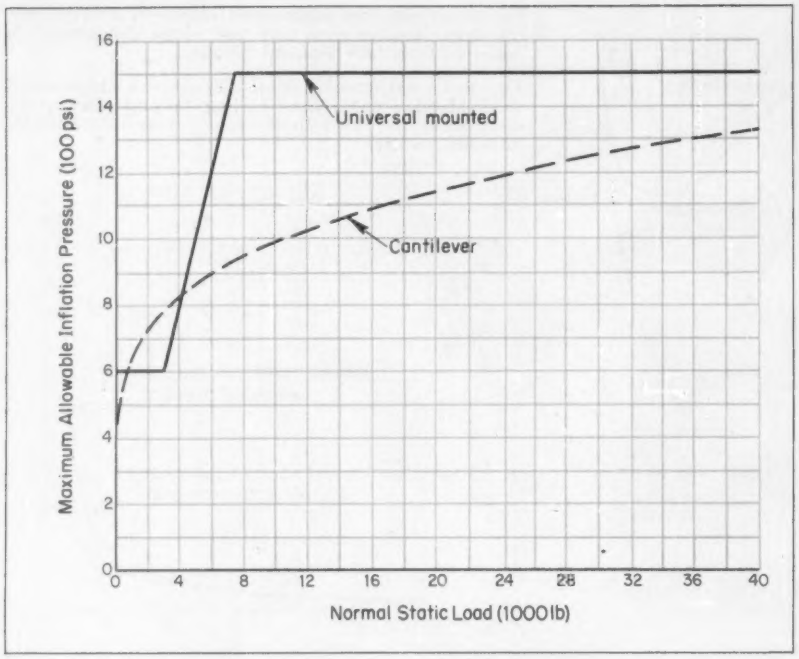


Fig. 4—Maximum allowable inflation pressure under normal static load for cantilever and universal-mounted types of air-oil shock absorbers.

of air dissolving in the oil reduces the air-spring force. Under static conditions then, strut load is

$$P = \frac{V_{fs} + KV_o p_s}{V_{fs} + KV_o p_s - \frac{\pi}{4} D^2 x} P_{fs} \qquad (2)$$

For a slowly applied load, the air-compression process is essentially isothermal so that exponent $n = 1.00$. The saturation coefficient, K, for air dissolved in oil has been found to vary from 0.0038 to 0.0073 sq in. per lb, decreasing with an increase in temperature.[2] Since a finite time is required for the solution to become saturated, the air-dissolution effect is usually negligible in the case of dynamic loading. Fig. 3 shows a typical static-loading curve.

Note that under either dynamic or static loading, the air-spring effect is nonlinear. As shown by the plots in Fig. 2 and 3, spring rate increases with strut displacement.

Design Practices

Design of air-oil shock struts in the United States is governed primarily by military specification MIL-S-8552.[3] Although this specification is not mandatory for civilian applications, it is usually followed because it is based on considerable military experience with air-oil shock absorbers. Unless otherwise stated, the design practices given here are taken directly from this specification.

Mounting: There are two main ways of mounting a shock strut: 1. As a cantilever. 2. With universal joints at each end. The first method has been traditionally used for aircraft landing gears. However, it has the severe disadvantage that under side loading large bending moments are induced in the strut body. These moments are detrimental not only from a stress standpoint, but also because they increase the possibility of leakage through the strut bearing.

Because of this disadvantage of cantilever mounting, universal-mounted struts have been coming into more widespread use. Except for universal-joint friction forces, which are practically negligible, the loading with this kind of mounting is strictly axial. Although MIL-S-8552 does not limit mounting methods to the universal type, use of this arrangement is encouraged indirectly by placing greater design penalties on the cantilever mounting arrangement.

Oil Level: When the strut is in the fully extended (no load) position, the minimum height of oil above the orifice should be 1¼ times the piston diameter where this diameter is 4 in. or less. For piston diameters larger than 4 in., minimum oil depth should be 5 in. The purpose of having a definite amount of oil above the orifice is to ensure proper orifice operation under all required conditions.

Inflation Pressure: The inflation pressure under normal static load should be 4 times the pressure when the strut is fully extended under no load and ⅓ of the pressure when the strut is fully compressed statically. Fig. 4 gives the maximum inflation pressure under normal static load for cantilever and universal-mounted struts.

Strut Bearings: For cantilever-mounted struts, the strut bearings should be spaced so that the bearing stress does not exceed 5500 psi under design side load. Also, the distance between the outermost ends of the upper and lower bearings should be at least

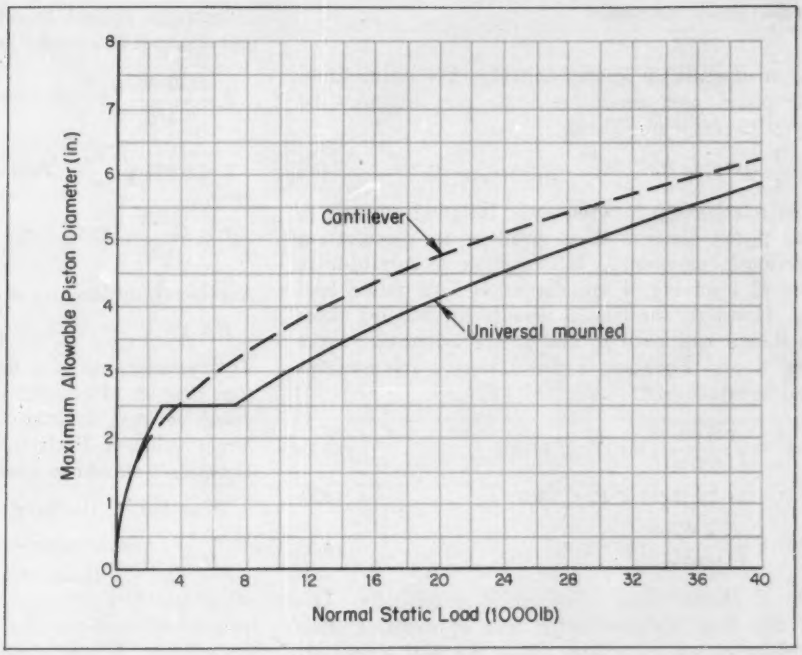


Fig. 5—Relationship of minimum allowable piston diameter to normal static load for cantilever and universal-mounted types of air-oil shock absorbers. Plots conform to recommended practice of MIL-S-8552.

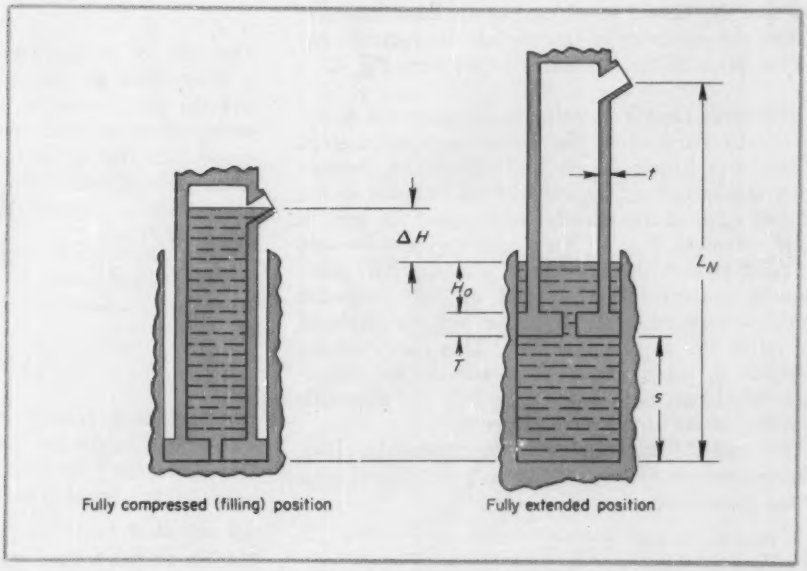


Fig. 6 — Dimensional relationships for estimation of minimum net strut length.

3 diameters. For universal-mounted struts, which have little tendency for binding, this distance need be only 1¼ diameters. For either type of mounting, this distance should be at least 2 in.

Basic Design Parameters

Stroke: Equating the energy absorbed in the strut with the kinetic energy of impact and solving for stroke,

$$s = \frac{12\,P_a\,v^2}{2g\,\eta\,P_{max}} \qquad (3)$$

where strut efficiency η is defined by (See Fig. 2)

$$\eta = \frac{\text{Area under dynamic load-displacement curve}}{s\,P_{max}} \qquad (4)$$

In the preliminary stages of design, strut efficiency must be estimated from past experience. Typical values range from 0.70 to 0.90.

Maximum permissible dynamic load P_{max} depends upon the particular application. It should be low enough to be withstood by the remainder of the structure to which the shock strut is attached.

Piston Diameter: Usually the normal static load,

P_s, on the strut is known initially. For equilibrium, the piston area times the static pressure must be equal to this load. Thus,

$$\frac{\pi}{4} D^2 p_s = P_s \tag{5}$$

The relationship between static inflation pressure p_s and piston diameter D is given in the specification previously mentioned. It is possible to substitute p_s and D from Fig. 4 into Equation 5 to obtain load P_s. However, the load is usually the starting point in design and both p_s and D are unknown. From Fig. 4 and Equation 5 the following relationships can be established:

$$D = \sqrt{\frac{4 P_s}{600 \pi}}, \quad 0 < P_s < 2940 \tag{6.1}$$

$$D = 2.5 \text{ in.}, \quad 2940 < P_s < 7360 \tag{6.2}$$

$$D = \sqrt{\frac{4 P_s}{1500 \pi}}, \quad 7360 < P_s \tag{6.3}$$

Fig. 5 shows these relationships graphically. Use of this chart reduces design time by avoiding trial-and-error determinations. Since the plot gives only the minimum piston diameter, the next larger standard seal size should be selected as the final diameter. When the diameter is determined, the required inflation pressure can be readily found from Fig. 4.

Net Strut Length: Another basic parameter which is usually required in the preliminary-design stage is net strut length L_N. It is the minimum distance from the bottom of the cylinder oil chamber to the bottom edge of the oil-filler neck when the strut is fully extended, Fig. 6. Since it is standard practice to fill a strut with oil when it is in the fully compressed position, the oil level at fully extended position depends upon the metal volume displaced by oil as the strut is extended. This metal volume depends on the piston diameter and the wall thickness which, in turn, is determined by the allowable working stress of the strut material.

To simplify the number of parameters involved, the estimate of minimum L_N given here is based upon these assumptions:

1. Strut is universal mounted.
2. Pressure p_s is related to D by Fig. 4.
3. Piston diameter D is related to load P_s by Fig. 5.
4. Requirements of specification MIL-S-8552 for minimum height of oil above the orifice are followed.
5. Piston wall thickness t is uniform along its length.
6. Maximum value of ratio D/t is 50. This ratio value is usually determined by machining considerations. However, smaller D/t ratios may be required sometimes to prevent buckling.

From Fig. 6,

$$L_N = H_o + T + 2s + \Delta H \tag{7}$$

Oil height H_o at fully extended position is 1.25 D for loads up to 18,880 lb, 5 in. for greater loads.

Assume that the ratio of orifice diameter to D is 0.20 and that Poisson's ratio is 0.285. Then, the thickness of the orifice plate, taken to be a thin annular plate subject to uniform pressure on its face and clamped at its outer periphery, is:[4]

$$T = \frac{20.45}{\sqrt{C}}, \quad 0 < P_s < 2940 \tag{8.1}$$

$$T = 0.377 \sqrt{\frac{P_s}{C}}, \quad 2940 < P_s < 7360 \tag{8.2}$$

$$T = \frac{32.3}{\sqrt{C}}, \quad 7360 < P_s \tag{8.3}$$

Another controlling requirement is,

$$T = t \tag{9}$$

This relationship is based on the conventional design practice of making the end plate of a pressure vessel at least as thick as the wall thickness. The larger value of T given by Equations 8.1 to 8.3 or Equation 9 should be used.

From Fig. 5, the drop, ΔH in oil height is,

$$\Delta H = \frac{\text{Area of piston-wall cross section}}{\text{Inside area of piston}} s = \frac{4\left(\frac{D}{t} - 1\right)}{\left(\frac{D}{t} - 2\right)^2} s \tag{10}$$

The ratio of piston diameter D to wall thickness t is determined by the maximum dynamic pressure and the design working stress S_w. For the working stress, either the yield strength or the ultimate tensile strength divided by the factor of safety may be used. Also, the maximum dynamic pressure is equal to the normal static pressure, p_s, times the dynamic-load factor, N. Thus,

$$\frac{D}{t} = 1 + \frac{2C}{P_s} \tag{11}$$

or

$$\frac{D}{t} = 50 \tag{12}$$

whichever is the smaller value.

The net length for zero stroke, L_{N0}, is obtained from Equation 7 by setting s and ΔH, which is proportional to s, equal to zero. Thus,

$$L_{N0} = H_o + T \tag{13}$$

Plots of L_{N0} versus normal static load for different values of material factor C are given in Fig. 7. As can be seen, the effect of factor C is quite small. To account for the effect of stroke variation, change in L_N for an incremental change in stroke s can be determined from

$$\frac{\partial L_N}{\partial s} = 2 + \frac{4\left(\frac{D}{t} + 1\right)}{\left(\frac{D}{t} - 2\right)^2} \tag{14}$$

Results of this calculation are plotted in Fig. 8.

Oil Volume: The volume of oil required to fill the strut can be estimated from

$$V_o = \frac{\pi}{4} (D - 2t)^2 (L_N - s) \tag{15}$$

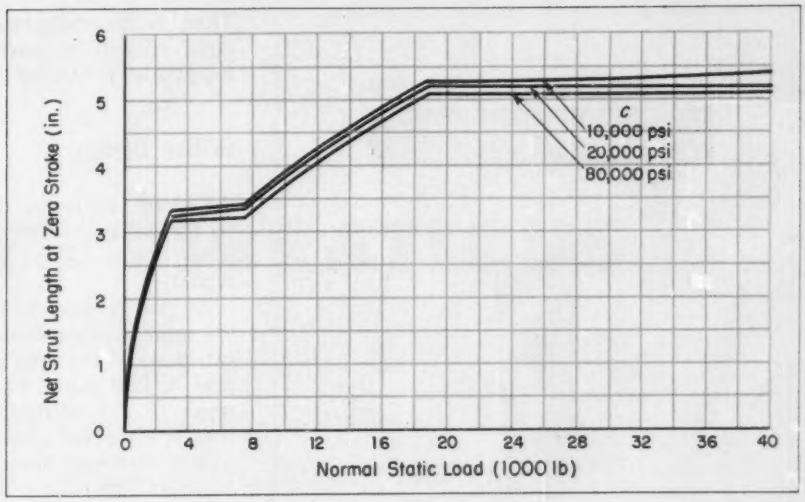


Fig. 7—Relationship of minimum net strut length at zero stroke to normal static load for a universal-mounted air-oil shock absorber. Plots are based on a maximum diameter-thickness ratio, $D/t = 50$. Correction factors for actual stroke are given in Fig. 8.

Air-Cushion Volume: When the strut is in the fully compressed position, the air volume required to realize any particular ratio of fully compressed pressure to fully extended pressure can be determined from

$$V_{fc} = \frac{\frac{\pi}{4} D^2 s}{\frac{p_{fc}}{p_{fe}} - 1} - K V_o p_a \qquad (16)$$

The pressure ratio which satisfies the specification is: $p_{fc}/p_{fe} = 4/(1/3) = 12$.

Static Strut Displacement: The strut position, measured from the fully extended position, which corresponds to the normal static load on the strut is

$$x_s = \frac{V_{fe} + K V_o p_a}{\frac{\pi}{4} D^2} \left(1 - \frac{p_{fe}}{p_s} \right) \qquad (17)$$

Design Example

A universal-mounted air-oil strut is to be designed to absorb the energy from a falling 5000-lb weight without allowing strut loads to exceed 20,000 lb. The weight is dropped vertically and hits the strut with an initial velocity of 12 ft per sec. Design objective is to find the most compact and lightest strut construction using one of two materials: A high-strength alloy steel with a working stress of 120,000 psi or an aluminum alloy with a working stress of 40,000 psi.

From Equation 3, assuming a strut efficiency of 0.80,

$$s = \frac{12(5000)(12)^2}{2(32.2)(0.80)(20{,}000)} = 8.39 \text{ in.}$$

From Fig. 5, the minimum piston diameter for a universal-mounted strut with static load P_s = 5000 lb is 2.50 in. Since this is a standard O-ring diameter it can be used as the final piston diameter. Then, from Fig. 4, the inflation pressure corresponding to a 5000-lb normal static load is 1020 psi.

Dynamic-load factor $N = 20{,}000/5000 = 4$. Then the material factor C is 120,000/4 or 30,000 psi for

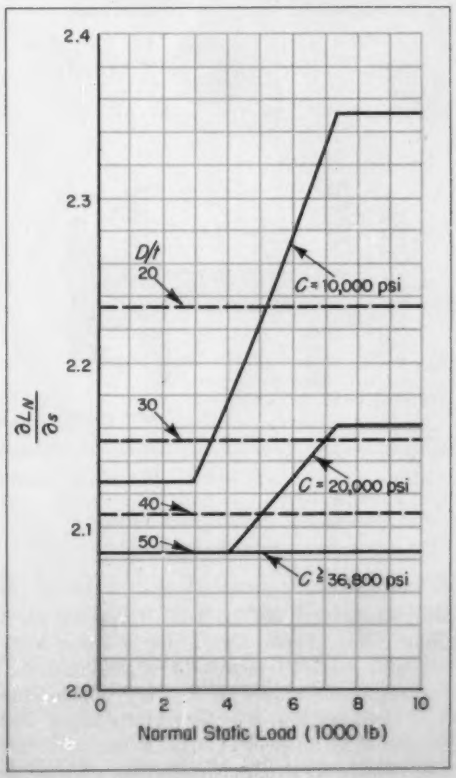


Fig. 8—Relationship of change in minimum net strut length per unit change in stroke to normal static load for a universal-mounted air-oil shock absorber. Solid-line plots represent recommended design practice and are based on a maximum diameter thickness ratio, $D/t = 50$. Dotted lines show effect of smaller values of D/t on design.

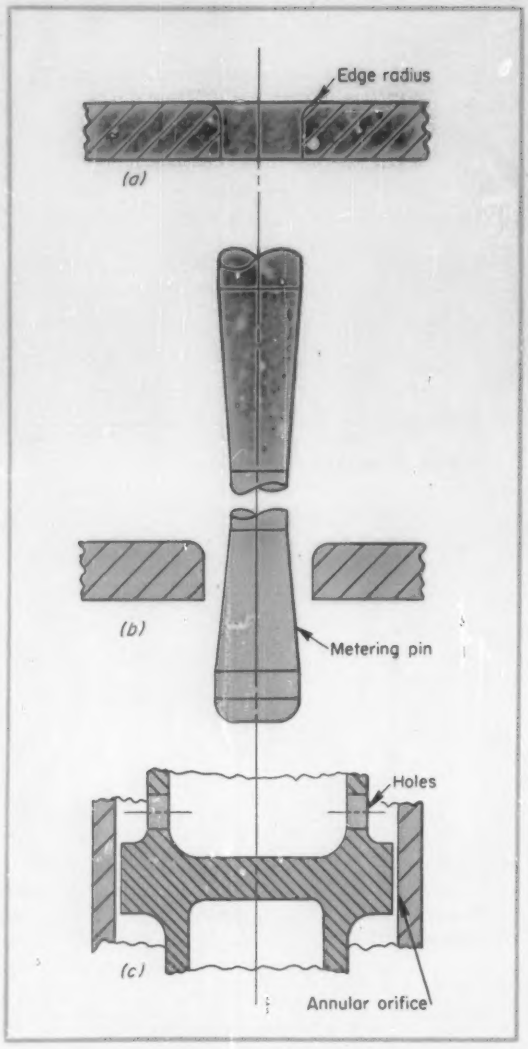


Fig. 9—Three types of orifices for air-oil shock absorbers: *a*, simple; *b*, variable flow area with metering pin; *c*, combination of annular and multiple-hole orifices.

the alloy steel, and 40,000/4 or 10,000 psi for the aluminum alloy. From Fig. 7, for a static load of 5000 lb and material factors of 30,000 and 10,000 psi, the respective values of L_{X0} are approximately 3.30 and 3.40 in. Fig. 8 gives corresponding values of 2.09 and 2.23 units of change in net strut length per unit change in stroke. Multiplying each of these values by the stroke of 8.39 in. gives 17.5 and 18.7 in. Finally, when each value of net strut length at zero stroke is added to the corresponding change in strut length, the estimated strut lengths for the steel and aluminum designs are, respectively, 20.80 and 22.10 in.

In this example, the net strut length for the steel unit would be only 1.30 inches shorter than for the aluminum design. However, this shorter length does not necessarily mean that the steel strut would be heavier in weight since fittings and attachments, as well as corner fillets, have not been considered. Thus, in the preliminary design stage, it is usually quite difficult to predict which of two materials would give the strut of lightest weight.

Orifice Design

Perhaps the most difficult and important step in the design of an air-oil shock absorber is the determination of the proper orifice size and configuration.

As can be seen from an examination of Fig. 2, the most efficient strut design is one in which the two peaks of the total dynamic load curve are identical in load value. The first peak is primarily the result of the oil-damping load while the second peak is composed almost entirely of air-spring load.

The customary design procedure is to first estimate an approximate orifice area. Then a series of drop tests is run, using a slightly different orifice area in each test until the optimum size is found. If the first peak of the total-load curve is higher than the second, the first peak can be decreased in the next drop test by using a larger orifice area.

There are varying degrees of complexity in orifice design. Obviously, the simple orifice, Fig. 9*a*, is desired if it gives an adequate drop-test load-displacement curve. If a simple orifice is not adequate, an orifice with variable flow area is usually necessary. Here, the variation in flow area is commonly provided by a variable-diameter metering pin, Fig. 9*b*. Design of this metering pin is usually determined from experience or by trial and error during a drop-test program. However, a mathematical method has been developed[5] for determining the shape of a metering pin which will result in a minimum value of the square of the acceleration integrated over the strut stroke.

An alternative to the metering pin arrangement is to mount the strut on a lever in such a way that the moment arm of the strut reaction force varies during the displacement of the strut. In general, it is desirable to have this moment arm increase rapidly at first and then at a lesser rate, finally becoming approximately constant near the end of the stroke.

Still another method of achieving a more efficient load-displacement curve is to use an annular orifice, Fig. 9c, in which the retarding force is mainly viscous (proportional to the first power of the velocity) instead of hydraulic (proportional to the square of the velocity). Although it is not widely used, the combination of multiple orifice holes and an annular orifice, as shown in Fig. 9c, has been found to be quite effective.

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PLATE VIBRATIONS

Nomogram for finding relationship between natural frequency, dimensions, and support conditions of plates.

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VIBRATION analyses of plates have always presented a problem because of the unlimited number of possible plate configurations and mounting arrangements. As an aid in design, this article presents a nomogram, Fig. 1, which relates the various plate design parameters to the fundamental natural bending frequency for current engineering materials.

The simplest and most direct method of preventing mechanical failures due to resonance is to increase the stiffness of the vibrating part so that the normal frequency band of the vibration environment will not excite resonance. Where this method is impractical, vibration dampers must be used.

General relationship for the natural vibration frequency of a plate of any configuration is

$$f_n = \frac{K}{2\pi b^2}\sqrt{\frac{Eg}{12(1-\nu^2)\rho}}$$

Mode factor K may be found from its exact differential solution for simple plate systems, or may be estimated fairly accurately by the Rayleigh-Ritz energy method. Solutions for specific plate conditions are detailed in the literature.[1-9]

A simplified expression for the natural frequency of a plate is possible when the modulus to density ratio, E/ρ, is taken as 103 x 10^6, and Poisson's ratio as 0.30. These conditions are valid for commonly used engineering materials such as steel, aluminum, and magnesium. Substitution of these values into the general frequency relationship gives

$$f_n = 9600\frac{Kh}{b^2}$$

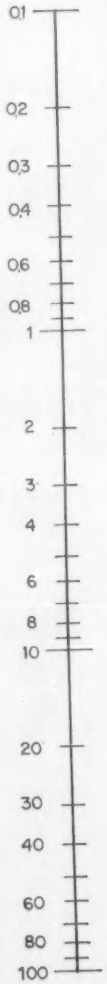
which is the basic equation solved by the nomogram.

The values of K for square and circular plates with various support conditions are designated on

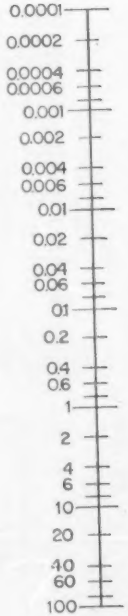
[1]References are tabulated at end of article.

Nomenclature

a, b = Side length, in.
E = Modulus of elasticity, psi
f_n = Natural bending frequency (first mode), cps
g = Acceleration due to gravity, in./sec^2
h = Plate thickness, in.
K = Mode factor
w = Width, in.
ν = Poisson's ratio
ρ = Density of plate material, lb/cu in.

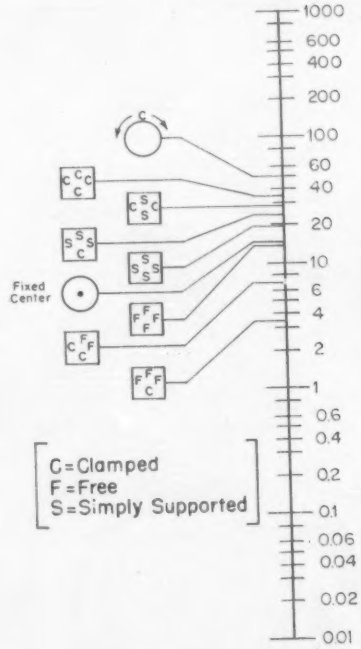


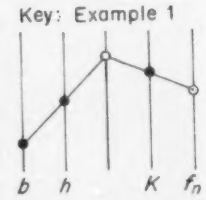
Width
w (in.)

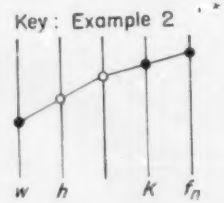


Thickness
h (in.)

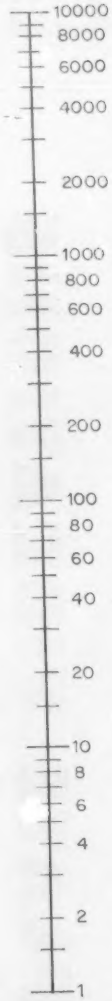
Pilot
Line





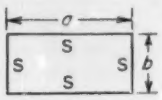
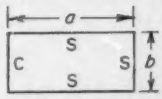
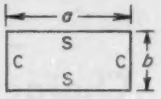
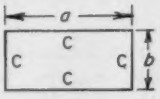


Mode Factor
K



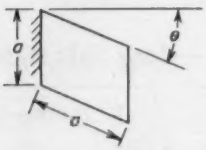
Frequency
f_n(cps)

Table 1—Mode Factors for Rectangular Plates

Ratio of sides, b/a	Mode Factor, K			
				
	Fig. a	Fig. b	Fig. c	Fig. d
0	9.87	9.87	9.87	22.37
1/3	10.97	11.14	11.36	23.19
2/5	11.45	11.75	12.13	23.77
1/2	12.34	12.92	13.69	24.57
2/3	14.26	15.57	17.37	27.00
1.5	14.26	18.90	25.05	27.00
2	12.34	17.33	23.82	24.57
2.5	11.45	16.63	23.27	23.77
3	10.97	16.26	22.99	23.19
∞	9.87	15.43	22.37	22.37

S = Simply supported; C = Clamped.

Table 2—Mode Factors for Skew Cantilever Plate



Skew Angle, θ (deg)	Mode Factor, K
15	3.60
30	3.96
45	4.82

the nomogram. Values of K for rectangular plates are shown in Table 1, and for a skewed cantilever plate in Table 2. Values of K for conditions lying between those given may be obtained with reasonable accuracy by interpolation.

For rectangular plates that are clamped or simply supported on two opposite sides, with the other sides free, normal beam analysis may be applied in determining natural frequency.[10]

Example 1: Find the fundamental resonant frequency of a plate that is hinged along all sides. The plate is 10 in. square and 0.25 in. thick.

SOLUTION: Connect points corresponding to 10 in. and 0.25 in. on the width and thickness scales, respectively, and extend the line to the pivot line. From this intersection, extend a line to the frequency scale passing through the K scale at the point for a square plate with four simply supported sides. The frequency is thus found to be 470 cps.

Example 2: A rectangular plate, 20 in. by 10 in., is to be used as a mounting surface for delicate equipment (assumed of negligible weight). The maximum vibration frequency expected during operation of the equipment is 2000 cps. What is the minimum plate thickness required to prevent resonance within this frequency range?

The plate is mounted such that two 20-in. sides are clamped, while the remaining two sides are simply supported.

SOLUTION: From Table 1 for this configuration, the mode factor is found to be 23.82 for a side ratio of 2:1. On the nomogram, a line is drawn through 2000 cps and 23.82 on the f_n and K scales, respectively, and extended to intersect the pivot line. A line drawn through this intersection and 10 in. on the width scale gives the required thickness of 0.90 in. on the thickness scale. The required plate, using the next largest nominal dimension, should be 1.00 in. thick.

Fig. 1—Nomogram for calculating natural frequency of plates from plate dimensions and support conditions. For circular plates, w = diameter; for rectangular plates, w = shorter side.

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Characteristics of

Constant-Speed Hydraulic Drives

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FOR many constant-speed applications, the hydraulic split system is a desirable means of power conversion. This article examines the applicability of such systems for a variety of constant-speed drive requirements.

Concepts: A split hydraulic system can be defined as one in which the output rotating component is separated from the input conversion component by fluid-transmission lines. Most applications of split-system constant speed drives can be covered by one of four basic systems, Table 1. Each system consists essentially of an engine-mounted hydraulic pump (power input), a remotely located hydraulic motor (power output), a reservoir, transmission lines, and controls to maintain constant output speed.

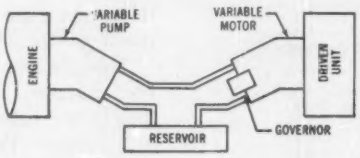
Since power is a function of pressure and flow, variations in load can be accommodated by changing pressure and flow. In Table 1, systems 1 and 2 use constant-pressure controls. Systems 3 and 4 use variable-pressure controls.

Some advantages of these systems are:

VERSATILITY: In addition to supplying constant-speed power, split systems are capable of meeting a variety of power requirements. For example, engine starting may be per-

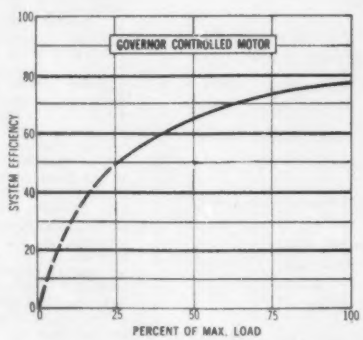
Table 1—Basic Split Hydraulic Systems for

1. Governor-Controlled Motor

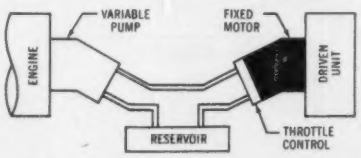


Constant-pressure fluid is provided by a pressure-compensated variable-displacement pump to a variable-displacement motor. Flow varies with load. Speed is sensed by a mechanical governor. Motor displacement is controlled by the governor signal. Pump output flow matches system demand.

Overload Ability: Sized for maximum power
Utility Hydraulic Power Ability: Inherent
Basic Speed Control: ±0.25 to ±1 per cent
Tuned Servo Speed Control: ±0.1 per cent
Engine Starting Ability: Yes, with extra control
Efficiency Characteristics:
With Load: High over wide range
With Speed: High over wide range

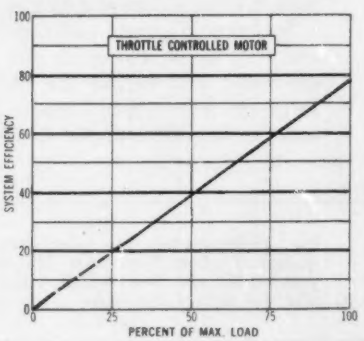


2. Throttle-Controlled Motor



Constant-pressure fluid is provided by a pressure-compensated variable displacement pump to a throttle valve and then to a fixed-displacement motor. Throttling is accomplished by sensing the pressure drop across a fixed orifice to control the position of the throttling spool. Motor pressure then varies to match the load. Pump output flow remains constant.

Overload Ability: Sized for maximum power
Utility Hydraulic Power Ability: Inherent
Basic Speed Control: ±2 to ±5 per cent
Tuned Servo Speed Control: ±0.1 per cent
Engine Starting Ability: Yes, with extra control
Efficiency Characteristics:
With Load: High over narrow range
With Speed: High over wide range



formed by supplying power either from a separate source or from an auxiliary power unit which uses the engine-mounted pump as a starter motor.

CONSERVATION OF SPACE: Split-system components are compact, and can be relocated without major system changes.

HEAT-REJECTION CAPABILITY: Hydraulic lines connecting split-system components dissipate system heat, minimizing heat-exchanger requirements and environmental problems.

System and Component Selection: To select one type of system from the four in Table 1, and to specify system components, consider these criteria:

DUTY CYCLE OF DRIVEN UNIT: System duty cycle and secondary functions determine the size of the power-conversion units and the specific type of control which best meets the requirements. A fan or blower could use system 2 because its load would be relatively constant. This type of system offers high efficiency over a relatively wide speed range, but only over a narrow load range. Conversely, a constant-head centrifugal pump, required to deliver varying amounts of flow at a relatively constant engine speed, could use the low-cost, low-weight system 4.

SPEED CONTROLS: The type of driven unit determines the basic requirements for speed regulation, and the mission of the driven unit decides the degree of control refinement. Speed-regulation capability varies with the type of control selected. However, close regulation is obtainable with any of the controls by adding a tuned servo loop for "trimming" speed.

SYSTEM POWER REQUIREMENTS: Maximum power requirements, together with speed and life factors, determine the size of the pumps and motors. It may be desirable to integrate the miscellaneous hydraulic components to minimize weight, conserve space, and improve reliability.

OVERLOAD AND RESPONSE: Both overloads and rapid response to sudden load changes require additional power. In systems 3 and 4 where load affects only pressure, the units have inherent capability, limited only by the relief valve setting, to supply the additional power.

ENGINE SPEED RANGE AND EFFICIENCY: Engine speed range is the ratio between maximum and minimum engine speeds during which a system is required to maintain constant output speed. Ranges are generally 2 to 1. Drive motor selection is independent of engine speed range, but the pump must be capable of transmitting sufficient power to the system at its lowest speed. The wider the engine speed range, the larger the pump required. System-efficiency curves are given in Table 1.

WEIGHT AND COST: A weight comparison by systems is shown in Fig. 1 for 1 and 15 kw designs. These quantities illustrate that system weight varies generally with basic speed control accuracy. The efficiency curves in Table 1 show that the lighter systems have more limitations in their performance characteristics. Tuned servo controls may be considered an approximately fixed weight, regardless of system power rating.

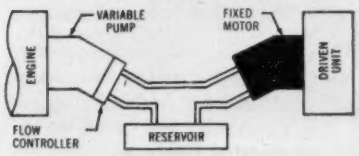
Proportional costs for the various types of systems are compared in Fig. 2. These charts for 1 and 15 kw systems also show the relative costs of fixed and variable-displacement pumps and motors. These relative costs, and weight savings, sometimes make the choice of the less versatile or less efficient systems attractive.

Applications: An example of the governor controlled drive, system 1, is shown in Fig. 3. The system supplies a turbine engine with 15 kva starting power, and 6.7 hydraulic horsepower at 3000 psi for flight control. It also provides capability for complete system check-out by simple ground hydraulic plug-in.

Multiple functions—close speed control and the aircraft mission—dictated the use of dual-purpose

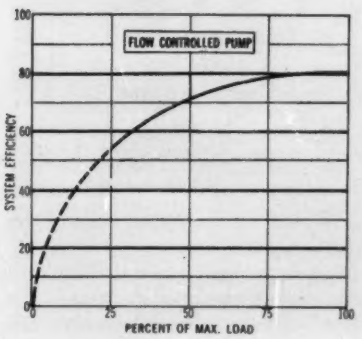
Low-Power Constant-Speed Drives

3. Flow-Controlled Pump

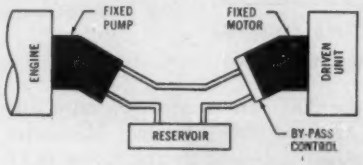


Constant flow is provided by a flow-controlled variable-displacement pump to a fixed-displacement motor. Pressure varies with load. As engine speed changes, the pressure drop across a fixed orifice is used to change pump displacement. Pump output flow remains essentially constant.

Overload Ability: Dependent on relief valve setting
Utility Hydraulic Power Ability: Special designs only
Basic Speed Control: ±3 to ±5 per cent
Tuned Servo Speed Control: ±0.1 per cent
Engine Starting Ability: Yes, with extra control
Efficiency Characteristics:
With Load: High over wide range
With Speed: High over wide range

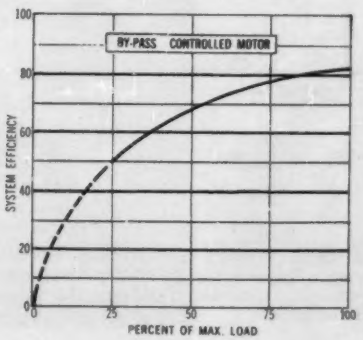


4. By-Pass Controlled Pump



Constant flow is provided by a fixed-displacement pump with a by-pass control to a fixed-displacement motor. Pressure varies with load. As engine speed changes, the pressure drop across a fixed orifice is used to change the amount of fluid by-passed to the reservoir.

Overload Ability: Dependent on relief valve setting
Utility Hydraulic Power Ability: Special designs only
Basic Speed Control: ±3 to ±5 per cent
Tuned Servo Speed Control: ±0.1 per cent
Engine Starting Ability: Yes, with extra control
Efficiency Characteristics:
With Load: High over wide range
With Speed: High over narrow range



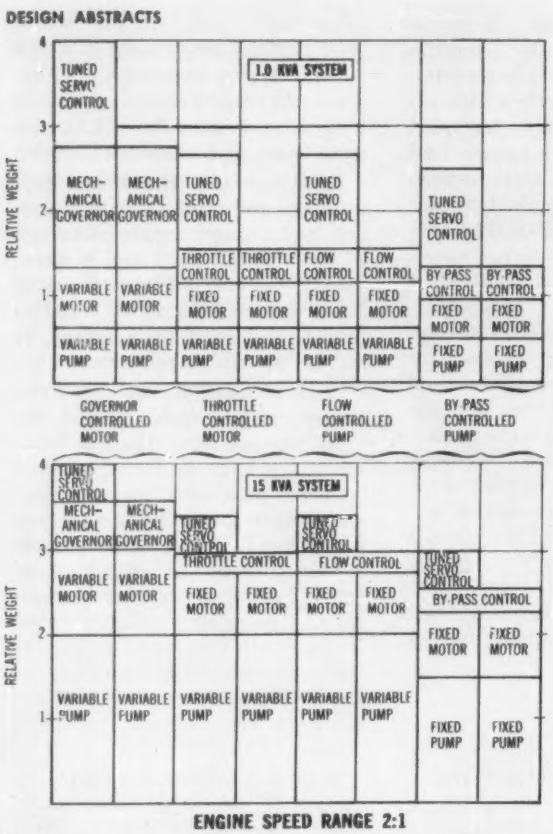


Fig. 1—Weights of split hydraulic constant-speed systems.

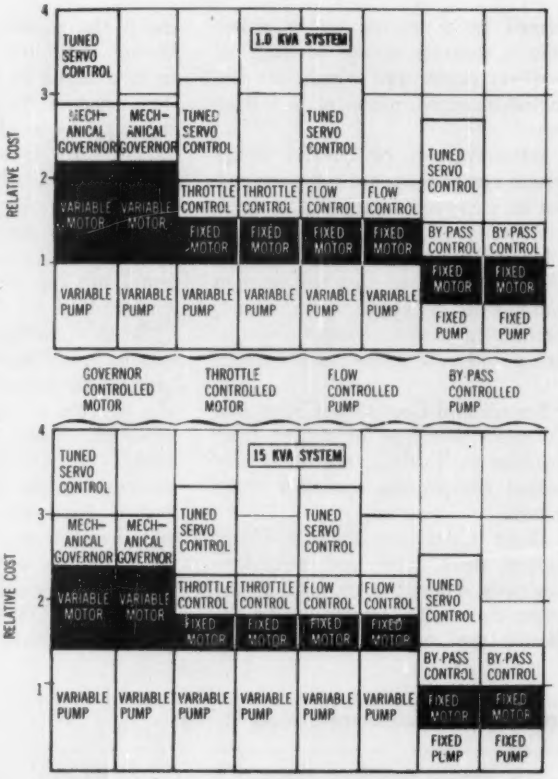


Fig. 2—Relative costs of split hydraulic constant-speed systems.

units (motor/pump), and a mechanical governor control to give the ±0.25 per cent speed regulation.

A constant-pressure system was selected as the most economical means of providing both hydraulic power to the constant-speed drive and hydraulic supply to the flight-control system.

An example of a throttle-controlled constant-speed drive, system 2, is an air-compressor drive for the Boeing 707. The unit is plugged into the 3000 psi constant-pressure aircraft hydraulic system. Maximum power delivered by the motor is 11 hp, and rated speed is 5500 rpm ±2.5 per cent. Total weight of the drive is 4.9 lb. The system 2 drive was selected on the basis of tying into a constant-pressure system with a unit which was required to deliver a relatively constant load at no closer than ±5 per cent speed regulation.

An example of a load-sensitive drive, system 3, includes a flow-controlled variable-displacement pump, fixed-displacement hydraulic motor, 9 kva generator, and a 40 cu in. self-pressurizing reservoir. This system provides electrical power for airborne navigation equipment. The system has a maximum pressure of 4500 psi, flow of 13.4 gpm, and maximum overload capacity of 18 kw. The hydraulic motor operates at 8000 rpm ±2.5 per cent and the pump operates over a 3:1 engine speed range. System weight is approximately 90 lb.

Paper 1, "Low Power Constant Speed Drives," presented at the Tenth Annual Aircraft Hydraulic Conference, at Vickers Inc., Detroit, Nov., 1960, 7 pp.

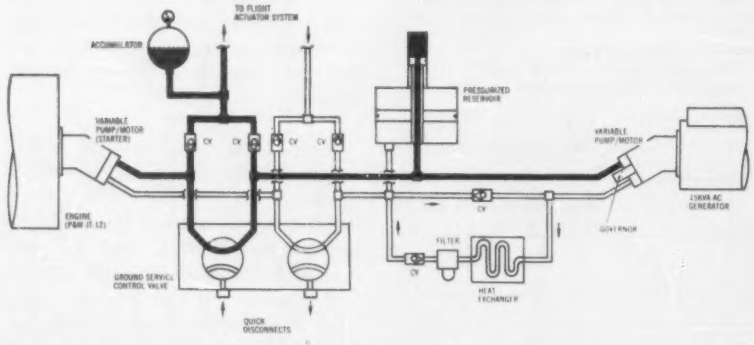


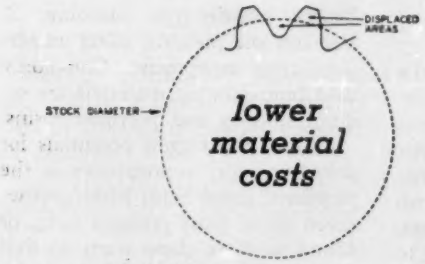
Fig. 3—Governor-controlled dual-function split system. During the start cycle, the ac motor-generator drives the motor-pump as a pump. This unit supplies hydraulic power to the engine-mounted pump-motor which operates as a motor. Following the start cycle, the starter unit operates as an engine-driven pump.

materials

Oxidation of Copper

A. Ronnquist, Dept. of Inorganic Chemistry, University of Uppsula, Sweden, and H. Fischmeister, Swedish Institute of Metal Research, Stockholm

A review of published papers on the oxidation of copper, with emphasis on work done in the last decade. Experimental techniques and theoretical rate laws are dis-



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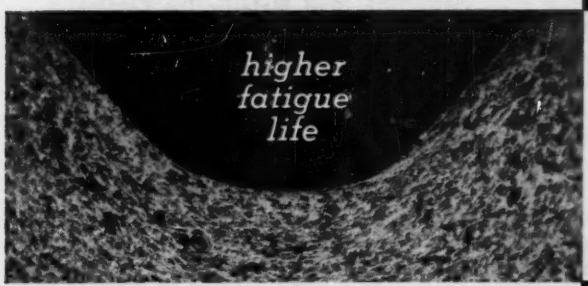

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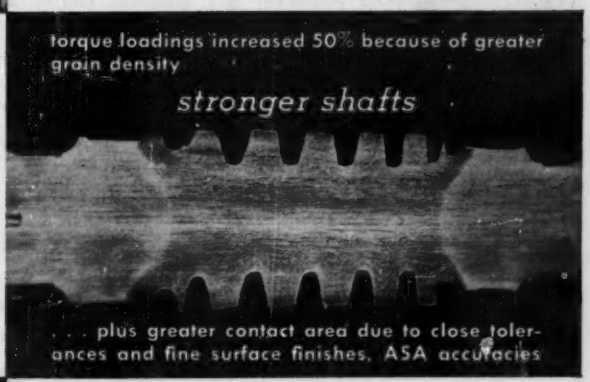

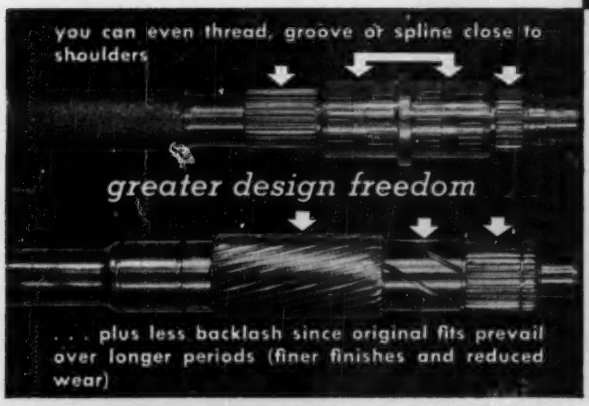

Ask for Bulletin RF-60MD on "Roto-Flo Chipless Machining"...

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Circle 465 on Page 19

cussed. Oxidation isotherms in the range 18 to 1020 C show that for data obtained at high temperatures there is good agreement between the various investigators, but that at lower temperatures the agreement is poor. At low temperatures, quasi-logarithmic oxidation seems to prevail. Over an extended range of intermediate temperatures, oxidation ranges from cubic to parabolic, while at high temperatures the parabolic law is generally obeyed.

Institute of Metals Paper No. 2028, "The Oxidation of Copper," Journal of the Institute of Metals, Vol. 89, 1960-61, pp. 65 to 76.

New Light-Weight Material For Permanent Magnets

R. B. Falk and G. D. Hooper, Metallurgical Products Dept., General Electric Co., Edmore, Mich.

A highly anisotropic structure having a composition in the region 28 Co, 57 Fe, and the balance oxygen. By suitably controlling the amount of oxygen, high intrinsic coercive forces, typical of ferrite structures, as well as high saturation magnetizations can be achieved. Permanent magnets, having a physical density of 3.7 grams per cu cm, were prepared from this material.

Paper No. 70, "A New, Light Weight Material for Permanent Magnets," presented at the Sixth Annual Conference on Magnetism and Magnetic Materials, New York, Nov., 1960.

processes

Impregnation Materials And Techniques

George J. Caudron, vice president, American Metaseal of Detroit

The process of infiltrating the open pores of a material, using a suitable vehicle. Impregnation was once thought of only as a salvage process. Today, designers consider impregnation in the original design of pressure-tight parts or parts to be plated. Success of the process depends upon two factors: Infiltration of pores, and retention of material in pores by capillary action.

Two impregnation methods are now used and widely accepted: 1. Internal pressure, using a jig and fixture transfer-type machine. 2. Vacuum and pressure, using immersion type equipment. Commonly used impregnating materials are sodium silicates and polyester resins.

One of the biggest potentials for polyester resin impregnators is the powdered metal field: Making powdered metal parts pressure tight, or filling voids in these parts so that they may be plated. There is no substitute for this material in this application. Even formulated silicates will not make the powder metal parts pressure tight because of the large volume of pores, usually 20 to 30 per cent by volume.

SDCE Paper No. 20, "Advance in Impregnation Materials and Techniques," presented at the First National Die Casting Exposition & Congress, Detroit, Nov., 1960, 7 pp.

Cost Comparisons of Plastic And Metallic Die Castings

Wm. O. Bracken, Plastics Sales, Cellulose Products Dept., Hercules Powder Co.

How plastics, with a Young's modulus ranging from 200,000 to 400,000 psi can compete with the much more rigid metals (modulus of 6 to 10 million psi) which also have a relatively low cost per pound. In an area where there has been no formalized approach to making comparative cost estimates, the method outlined here may be helpful in making summary estimates of reasonable accuracy.

SDCE Paper No. 17, "Plastics—Competitor of Die Castings," presented at the First National Die Casting Exposition & Congress, Detroit, Nov., 1960, 15 pp.

mechanical

Noise in Diesel Engines

T. Priede, principal research engineer, C.A.V. Ltd., Middlesex, England

Frequency analysis of cylinder pressure as a satisfactory criterion of the "noisiness" of a cylinder-pressure diagram. The effect of the properties of the measuring equipment, such as band width, is considered so that the results may be interpreted quantitatively in terms of the pressure rises and, hence, the amount of combustion involved. In some cases, stroke-to-stroke variations are important, and frequency analysis and emitted noise are com-

pared in relation to background noise. Over a limited range, the effect of type of combustion chamber is explored.

IME Paper No. AD-5/60, *"Relation Between Form of Cylinder-Pressure Diagram and Noise In Diesel Engines," presented at a meeting of the Automobile Div., IME, London, Nov.,* 1960, 15 *pp.*

Calculations for Fuel-Injection Systems

B. E. Knight, acting chief engineer, C. A. V. Ltd., Acton, Middlesex, England

A simplified method of calculating injection system performance for the use of applications engineers. It is particularly relevant to the problem of avoiding secondary injection and dribble.

Agreement with experiment confirms that all important factors have been taken into account. Methods used for dealing with compression waves in pipes are described in detail. Viscous friction and voids in the fuel are taken into account.

A longer term objective is the reduction of the time required to match injection equipment to engines by using this and other computer programs instead of experimental methods, up to the final trial stage.

IME Paper No. AD 2/60, *"Fuel-Injection System Calculations," presented at a meeting of the Automobile Div., IME, London, Nov.,* 1960, 9 *pp.*

TO OBTAIN COPIES of papers or articles abstracted here, write directly to:

The Institute of Metals, 17 Belgrave Square, London S.W. 1, England.

IME—The Institution of Mechanical Engineers, 1 Birdcage Walk, Westminster, London S.W. 1, England.

SDCE—The Society of Die Casting Engineers, 19382 James Couzens Highway, Detroit 35, Mich.

Sixth Annual Conference on Magnetism and Magnetic Materials, sponsored by the American Institute of Electrical Engineers, 33 West 39th St., New York 18, N. Y., and the American Institute of Physics, 335 East 45th St., New York 17, N. Y.

Tenth Annual Aircraft Hydraulics Conference, sponsored by Aero Hydraulics Div., Vickers Inc., Detroit 32, Mich.

Circle 467 on Page 19

Helpful Literature
for Design Engineers

For copies of any literature listed, circle Item Number on Yellow Card—page 19

Fittings and Flanges

Booklet FB-502A discusses seamless welding fittings and flanges in carbon, alloy, and stainless steels. Booklet includes charts of standard sizes and schedules according to ASA B36.10 and B36.19. It also contains a comprehensive breakdown of dimensional tolerances, illustrations of most commonly produced fittings and flanges, and chart of sizes and types available. 8 pages. Tubular Products Div., Babcock & Wilcox Co., Beaver Falls, Pa.

Circle 601 on Page 19

Strain-Gage Accelerometer

Smallest temperature-compensated, strain-gage accelerometer available is described in Bulletin 4202. Unit is pictured, and dimensional drawing is provided as well. Sections on description, design features, and complete specifications are incorporated. 2 pages. Consolidated Electrodynamics Corp., 360 Sierra Madre Villa, Pasadena, Calif.

Circle 602 on Page 19

Stand-Off Fasteners

Information on all types of stand-off fasteners used to support tubing, wire bundles, conduit, equipment, and instruments is offered in new, illustrated booklet. "What You Should Know About Stand-Off Fasteners" covers subjects such as: Advantages and disadvantages of various designs and materials; installation costs and how to reduce them; when to use special types; how to select fasteners; causes of failure. 18 pages. Western Sky Industries, 21301 Cloud Way, Hayward, Calif.

Circle 603 on Page 19

Photoelectric Control

Catalog IB-2 contains information about Infrabeam, an infrared photoelectric control which functions by reflected or interrupted beam over an extremely long range, even under high general light conditions. Typical materials handling, counting, inspection, and control installations are illustrated. Detailed specifications and descriptions of models and accessories are provided. 8 pages. Electronics Div., Cramer Controls Corp., Centerbrook, Conn.

Circle 604 on Page 19

Die-Stamped Circuits

"Designing With Die-Stamped Circuits," Bulletin D1 contains three sections. First compares each of the features of die-stamped circuits with those made by etching copper-clad laminated plastics. Advantages of the die-stamped circuits are pointed out. Second section provides hints for the design of the circuits, including layout, fabrication, artwork, nomenclature, and current-carrying capacity. Also included are standard tolerances for fabricating the die-stamped circuits. Final section gives definitions for the most common terms used in printed-circuit design. 12 pages. Dytronics Inc., 115 Main St., Rochester, Mich.

Circle 605 on Page 19

Band Clamps and Couplings

Industrial Catalog 803 contains full information on a complete line of industrial band clamps, hose clamps, couplings, flanges, and V-band joints for all applications. Complete design information is given for engineers designing original equipment. Comprehensive product dimensional and operating data provide facts needed for original product-design work. All products are pictured, and many graphs, tables, and dimensional drawings are included. 44 pages. Marman Div., Aeroquip Corp., 11214 Exposition Blvd., Los Angeles 64, Calif.

Circle 606 on Page 19

Snap-Action Switches

New 1961 catalog of precision snap-action switches features a four-page technical discussion of switches and switch terminology, as well as complete and concise product descriptions. Electrical ratings, dimensions, switch life information, and operating characteristics are given for all basic switches. Product descriptions of hermetically sealed and environment-free switches also appear. 32 pages. Licon Div., Illinois Tool Works, 6606 W. Dakin, Chicago 34, Ill.

Circle 607 on Page 19

Strain Gages

Characteristics of new line of semiconductor strain gages are given in Bulletin K-101. Principle of operation is explained, and table of gage characteristics for the several types is included. Advantages of these units are pointed out. 4 pages. Kulite-Bytrex Corp., 50 Hunt St., Newton 58, Mass.

Circle 608 on Page 19

Lock Nut

FN 1014 elevated-temperature lock nut that exceeds aircraft and missile industry standards for 800-F applications is described in Form 2686. Convenient tabular summary compares physical properties of the new nut with the NAS 1291C standard for 800-F applications. Bulletin reviews areas of specification information on the fastener. Size ranges and interchangeability with other nuts by NAS and AN numbers are provided in the specification data. 4 pages. Standard Pressed Steel Co., Box 102, Jenkintown, Pa.

Circle 609 on Page 19

Rotary Actuators

Catalog HYD-1 describes precision hydraulic rotary actuators for industrial applications. Specifications, tables, graphs, and dimensional drawings are provided for the five general size categories. General operation of the units is explained. 16 pages. Buffalo Hydraulics Div., Houdaille Industries Inc., 537 E. Delavan Ave., Buffalo 11, N. Y.

Circle 610 on Page 19

Atomized Metal Powders

Elemental and prealloyed metal powders are described in a new brochure. The fine, pure metal or alloy powders can be controlled in both size and shape. They include stainless steel, both spherical and irregular; commercially pure iron; silver; copper; aluminum-copper-nickel alloys; cobalt-chromium; and other cobalt alloys. Booklet gives microscopic color photographs of some of the powders produced, and also provides a list of current applications. 4 pages. Federal-Mogul Div. Research & Development, Federal-Mogul-Bower Bearings Inc., P. O. Box 1048, Ann Arbor, Mich.

Circle 611 on Page 19

Directional-Control Valves

Form W-1-2-3-4 describes two, three, and four-way selector control valves for hydraulic systems to 3000 psi. Catalog details the advantages of the valves, and includes data on dimensions, specifications, and ordering information. 16 pages. Special Products Div., Weatherhead Co., 300 E. 131st St., Cleveland 8, Ohio.

Circle 612 on Page 19

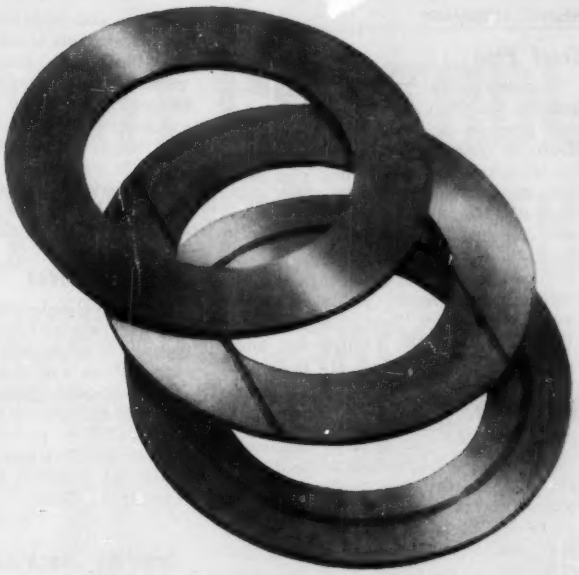
Molding Material

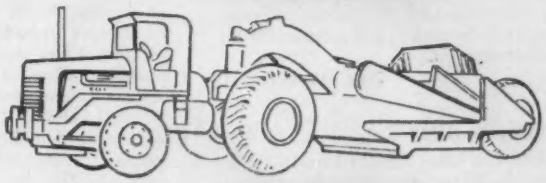
Descriptive booklet of the properties, uses, and molding requirements of compounds based on Dapon diallyl-phthalate resins is now available. Included are 13 tables giving performance data. Another section deals with the effect of various mineral and synthetic fillers on molded properties. Typical properties chart for molding compounds based on Dapon resin is also included. 26 pages. Dapon Dept., Food Machinrey & Chemical Corp., 161 E. 42nd St., New York 17, N. Y.

Circle 613 on Page 19

HOW TO SOLVE A WEIGHTY PROBLEM (120,000 LBS. WORTH UNDER SHOCK LOADS)...

The single Spauldite wear plate shown below replaced one aluminum bronze and two steel washers at the spindle pivot between a scraper-loader and its tractor. Spauldite provided better wear under shock loads estimated at 120,000 pounds, eliminated the need for lubrication and reduced cost by 40%.





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Steel Pipe

Complete data on corrosion-resistant qualities and physical features of Yoloy steel pipe are provided in new brochure. Available in continuous weld and seamless standard and extra-strong pipe sizes, it is a copper-nickel, high-strength, low-alloy steel. Resistance to atmospheric, soil, and chemical corrosion is illustrated in charts and graphs, comparing the pipe with carbon steel and wrought iron. Other charts compare tensile, yield, and impact strengths. 8 pages. Youngstown Sheet & Tube Co., Box 900, Youngstown, Ohio.

Circle 614 on Page 19

Flow Meter, Transmitter

Magnarator through-flow pneumatic transmitting rotameter is described in Catalog 10A2150. Principle of operation is explained and pictured in detail. Information on models available, materials of construction, and pressure ratings is given. Bulletin provides full specifications and details on capacities and dimensions. 6 pages. Fischer & Porter Co., 716 Jacksonville Rd., Warminster, Pa.

Circle 615 on Page 19

Titanium Alloy

Titanium alloy Ti-8Al-1Mo-1V, which raises by 25 per cent the temperature ceiling of titanium for use in jet engines, is discussed in new data memorandum. Manual outlines forging and heat-treat procedures for the alloy, and includes discussion of creep, stability, and fatigue properties. Many charts and tables are incorporated. Titanium Metals Corp. of America, 233 Broadway, New York 7, N. Y.

Circle 616 on Page 19

Solenoids

New brochure provides details on Double-T solenoids, and points out the advantages of their use. Section on how to select the correct solenoid is incorporated. Four types are detailed, each including photograph, table of operating data, dimensional drawings, and pull and current curves. 8 pages. Controls Co. of America, 9555 Soreng Ave., Schiller Park, Ill.

Circle 617 on Page 19

Control Assembly

Bulletin 3400-9-60 provides information on new Quadrastat control assembly which has applications wherever an infinitely variable, positive-positioning, self-locking control is required. Device prevents change of setting by vibration or feedback. Unit is pictured and described, and dimensional diagrams are included. 4 pages. Adams Rite Mfg. Co., Glendale, Calif.

Circle 618 on Page 19

Fuse Panels and Switches

Publication PL 12-29-660 is a product guide containing installation and application data on a complete line of fuse panels, service entrance equipment, general-purpose switches, general-purpose toggle switches, safety switches, industrial switches, and double-throw switches. Cabinet dimensions of all units are included. Engineering-data section gives allowable current-carrying capacities of insulated copper conductors in amperes, number of conductors in conduit or tubing, and load and circuit information for electrical systems. 20 pages. American Electric Switch Div., Clark Controller Co., 1146 E. 152nd St., Cleveland 10, Ohio.

Circle 619 on Page 19

Control Valves

Catalog J170-1 contains complete engineering information on sliding gate and plate control valves. Applications, operating features and characteristics, materials of construction, pressure and temperature limitations, photographs and cut-away sections, flow curve, sizing charts, and sample specifications are all provided. 8 pages. OPW-Jordan, 6013 Wiehe Rd., Cincinnati 13, Ohio.

Circle 620 on Page 19

Drafting Machine

Complete details on the operation of the Paragon Auto-Flow drafting machine are provided in new two-color illustrated brochure. Close-up photographs show how the automatic control system provides 360-deg indexing. Other features described are adjustable depth, swing-away movement, adjustable rail supports. 4 pages. Keuffel & Esser Co., Adams & Third Streets, Hoboken, N. J.

Circle 621 on Page 19

Lubricating Equipment

Bulletin 0400-B1 provides complete catalog listings as well as simplified engineering and application data on Crown filters, regulators, and lubricators. Each unit is completely diagramed, and is accompanied by dimensional drawings and tables. Full information about accessories is available, and a parts identification section is also included. 20 pages. Hannifin Co., Dept. 116, 501 S. Wolf Rd., Des Plaines, Ill.

Circle 622 on Page 19

Portable Oscilloscopes

New booklet gives a detailed presentation of seven available oscilloscopes with 3-in. cathode-ray tubes, including rack-mount models. Catalog contains complete specifications, performance characteristics, and pertinent illustrations for all seven instruments. 16 pages. Tektronix Inc., P. O. Box 500, Beaverton, Oreg.

Circle 623 on Page 19

Speed-Measurement Systems

Bulletin 1000 describes the operation and selection of self-generating, three-phase, electric speed-measurement systems which measure rotary movement with accuracy of 0.3 per cent of full scale within the linear range. Four component parts are described: Electric tachometer generators, electric tachometer indicators, explosionproof housings, and electromechanical vibrators. Easy-to-read scale chart in tabular form makes it simple to determine the rpm range for a specific drive ratio from 35 to 35,000 rpm. 4 pages. Meriam Instrument Co., 10920 Madison Ave., Cleveland 2, Ohio.

Circle 624 on Page 19

Welded-Steel Tubing

Weight computations for welded-steel tubing are easily obtained from tables contained in a new brochure. Tables give dimensions and weight per foot for round mechanical tubing to 10 in. diam, square and rectangular tubing to 5 in. OD, and pressure tubing to 5 in. Full-page table gives decimal equivalents for fractional parts of a pipe foot, and another presents diameters and weights for pipe sizes (plain ends). 16 pages. Electricweld Tube Div., Jones & Laughlin Steel Corp., 3 Gateway Center, Pittsburgh, Pa.

Circle 625 on Page 19

Test Point Connectors

Complete technical specifications, outline drawings, and illustrations describing an expanded series of test point connectors for printed-circuit applications are contained in Brochure TP1060. Table provides data on electrical ratings, and information on materials is also included. 6 pages. Electronics Div., DeJur-Amsco Corp., 45-01 Northern Blvd., Long Island City 1, N. Y.

Circle 626 on Page 19

Timing Motor

Series MD-83 direct-current timing motor is described in new folder. It gives details on construction features and operating advantages. Dimensional data drawings and complete information on ratings and availability of components are also included. 4 pages. Haydon Div., General Time Corp., 245 E. Elm St., Torrington, Conn.

Circle 627 on Page 19

Slip-Ring Assemblies

Catalog 100-S lists standard slip-ring and brush-block assemblies, including completely self-contained units. It provides complete details as to dimensions, ring and brush materials, speed ranges allowable, currents and voltages, and complete material specifications. 32 pages. Fabricast Inc., 9835 Alpaca St., South El Monte, Calif.

Circle 628 on Page 19

Adhesives, Coatings, Sealers

New catalog contains eight fold-out tables listing the uses, characteristics, and general properties of over 170 different adhesives, coatings, and sealers. Catalog is designed to help select the proper material for a specific application, and to help determine similarities and major differences between products having the same general base material. Cross-reference index lists over 200 different adhesive, coating, and sealer applications and refers to the section of the catalog where a product will be found for each of these specific applications. 12 pages. Write on company letterhead to Adhesives, Coatings and Sealers Div., Minnesota Mining & Mfg. Co., 900 Bush Ave., St. Paul 6, Minn.

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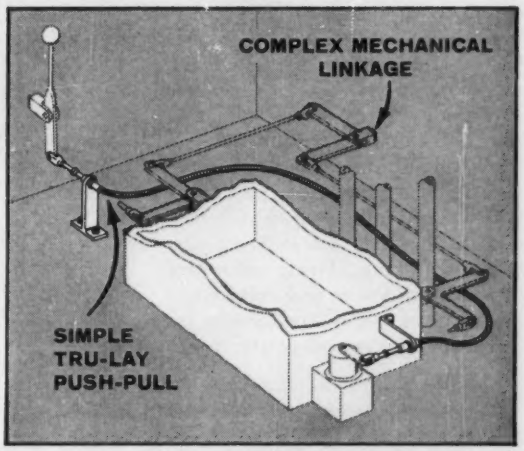
If your products involve remote control—electrical, hydraulic, pneumatic or direct—TRU-LAY PUSH-PULL FLEXIBLE CONTROLS can help solve your design problems. They provide positive remote control over short or long distances—up to 150 feet from the control point. Because they operate while flexing, they can snake around obstructions. They will not buckle. They are ruggedly constructed, easily installed and operated, sealed against dirt and moisture, and will handle jobs with as much as 1,000 lbs. input. PUSH-PULL CONTROLS are simple, have but one moving part, are noiseless and give a lifetime of accuracy. Mechanical linkages, on the other hand, are complex. Unlike PUSH-PULL CONTROLS, they are made of many parts, wear at many points, and produce increased backlash, vibration rattles and lost accuracy.



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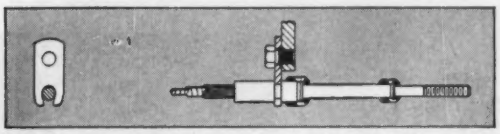
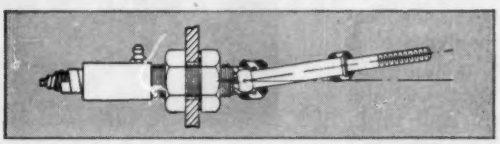
Anchorages



Clip anchorage • a simple clip for light loads



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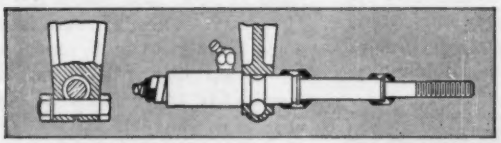

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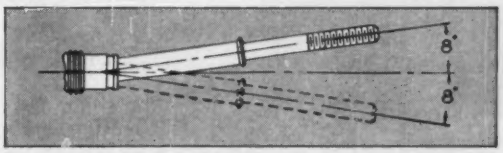
Swivel Action



Standard assemblies have end fittings with a swivel movement of ± 8° to compensate for misalignment and rise or fall of lever arms. Swivel joints, and the sliding ends, are sealed against dirt and moisture.

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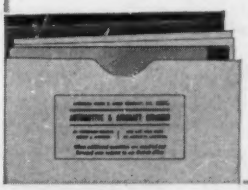

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is explosive-actuated unit

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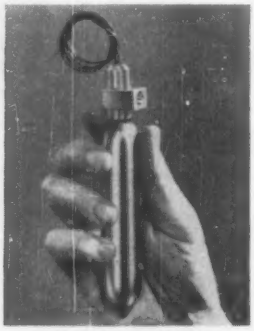


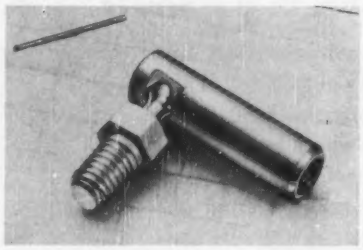
for safety and fire-extinguishing systems, control valves, pneumatic actuators, pressurizing and purging systems. Standard gaseous charge is nitrogen at 350, 500, 1000 or 1500 psi. Standard unit is 6½ in. long, holds 3 cu in. of gas, and weighs 5½ oz. **Conax Corp.**, 2300 Walden Ave., Buffalo 25, N. Y.

Circle 629 on Page 19

Miniature Ball Joint

for light uses where small size is required

Type FM ball joint has shell of only 27/32 in. long, ¼ in. diam. Ball screw is ⅝ in. long to ball center, with ¼ in. hex wrenching flats and 10-32 thread. Female threads in the tapped hole of the shell run from No. 4 to 10. Assembly gives full freedom of move-



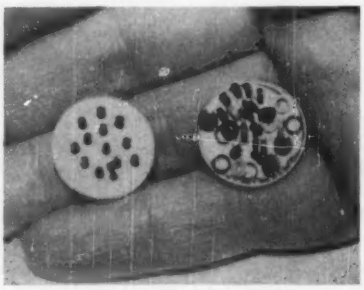
ment to the ball, with no binding at the neck. Entire unit is cadmium plated. Applications include carburetor and governor controls for small gasoline engines, power motors, outboard motors, and many electromechanical linkages. It is particularly useful for miniaturized servo-control systems, such as in missiles. **J. J. Tourek Mfg. Co.**, 1901 S. Kilbourn Ave., Chicago 23, Ill.

Circle 630 on Page 19

Miniature Resistor Parts

are machined from cast epoxy rods

Miniature and microminiature resistor bobbins, coil forms, and encapsulating cups have excellent electrical, mechanical, and chemical properties. Parts are produced with extreme accuracy and uniformity in sizes as small as 1/32 in. OD and 1/32 in. in length, to wall thicknesses of 0.004 in. Bobbins, coil forms, and cups are machined from high-strength cast epoxy rods which can be drilled, shaped, or ground with high-speed tools. Bobbin as-



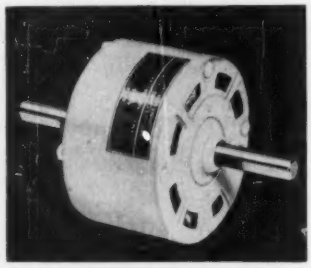
semblies are complete with termination tabs and leads. Special cup assemblies can be designed for chokes, coils, transformers, filters, semiconductors, and modules. **Omega Precision Inc.**, 755 N. Coney Ave., Azusa, Calif.

Circle 631 on Page 19

Fractional-Horsepower Motors

fit individual motor package needs

Two, four, and six-pole shaded pole, and six-pole split-capacitor motors are available for fractional-horsepower applications. Motors can be wound for 115, 208, or 230-v operation at 50 or 60 cycles, and can be engineered for single or double shafts, thermal protectors, special mounting rings, terminals, or other features to fit individual motor package needs. Smallest unit is a



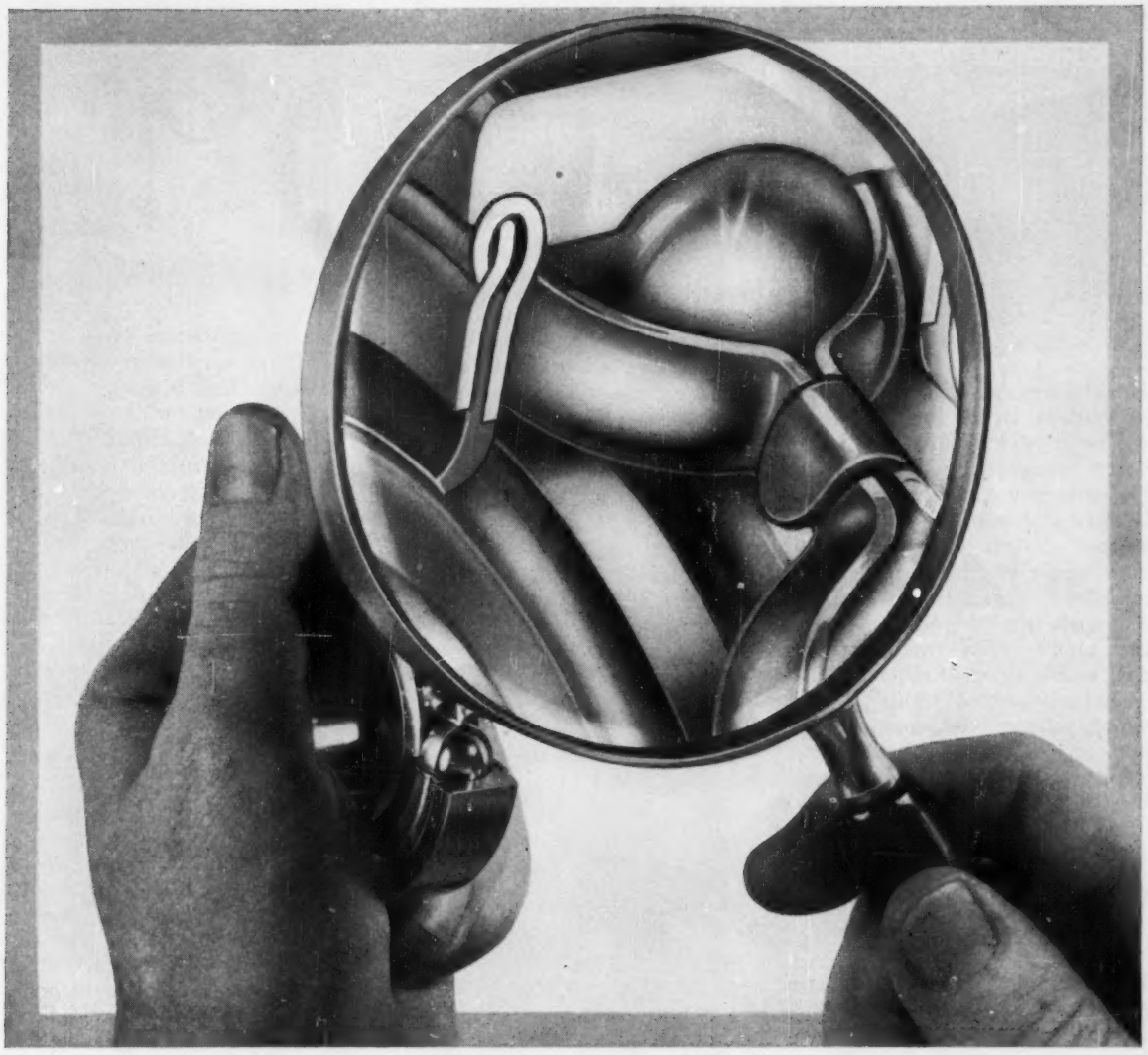
35-w, two-pole shaded-pole motor rated at 3000 rpm and 1/150 hp at 115 v, 60 cycles. Largest is a six-pole, permanent-split model rated at ⅓ hp and 1075 rpm. **Leece-Neville Co.**, 989 Athens St., Gainesville, Ga.

Circle 632 on Page 19

Motor Protection Switches

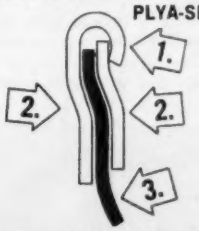
for motors of 1 hp or less

Weber M10 motor controllers, less than half the size of comparable motor-protection switches, are designed for use with polyphase, frac-



New FAFNIR seal in a "steel sandwich" stays put... seals better!

NEW "ROLLED-IN" FAFNIR PLYA-SEAL



1. Strong clamping action secures seal in bearing.
2. "Steel sandwich" provides rigid seal support, prevents push-in.
3. Tough, Buna-N rubber-impregnated fabric Plya-Seal offers "best protection yet" against contaminants, fumes, moisture.

Notice the steel supports on both sides of the seal in this Fafnir ball bearing. The seal is held by clamping action from the rolled-in, firmly wedged supporting members.

This new Fafnir seal design is engineered to prevent seal push-in, and to assure positive anchoring of the seal in the bearing. Protection against contaminants is increased . . . lubricant is more effectively locked in. Sealing is further improved by the "baffle action" of the inner steel support, and the lip-in-groove design of the seal itself.

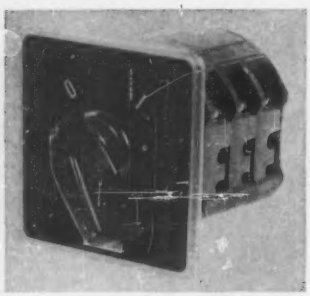
Fafnir ball bearings with new, "rolled-in," nonremovable Plya-Seals are now available in a wide range of sizes and in Fafnir power transmission units.

FAFNIR BALL BEARINGS

THE FAFNIR BEARING COMPANY
NEW BRITAIN, CONNECTICUT
Please send me more information on sealed and shielded bearings.

NAME..... TITLE.....
COMPANY.....
STREET.....
CITY & STATE.....

Circle 470 on Page 19



tional-horsepower motors. Switches are available for use from 0.07 amp to 1 hp at 440 v. They have a large rotary handle that moves through 90 deg to give a positive visual indication of overload, even from a distance. Switch cannot be held closed under any harmful overload conditions because mechanism is completely trip-free from the operating handle. After overload tripping, unit is automatically reset and ready for immediate reclosing. Built-in temperature compensating device compensates for changes in ambient temperature. **Wood Industries Inc.**, 26 Central St., Ipswitch, Mass.

Circle 633 on Page 19

Universal Joints

handle speeds to 1500 rpm

Universal joints for industrial applications to 1500 rpm are available in both single and double joints in a wide range of sizes. Single joints provide smooth, sensitive operation through a full working angle of 40 deg and double joints through 80 deg. Rated at 0.35 to 190 hp at 100 rpm, they are furnished in sizes from $\frac{3}{8}$ to 4 in. and are available with square bore. Case-hardened and fine alloy steels are used to achieve light weight and exceptional durability. Some sizes are also available in various

grades of stainless steel, and with bronze bushings surrounding the pins. **Lovejoy Flexible Coupling Co.**, 4882 W. Lake St., Chicago 44, Ill.

Circle 634 on Page 19

Aluminum Paint

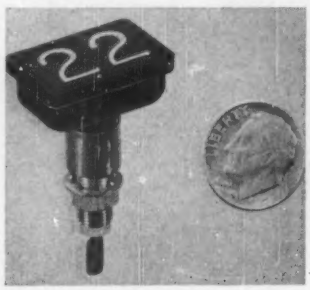
withstands temperatures to 1200 F

Heat-Rem H-120A aluminum paint, for either interior or exterior use, withstands temperatures to 1200 F. It can be applied by brush, spray, or dipping, and will air or bake dry. Of extra-heavy viscosity, it provides a thick, flexible coating, resistant to industrial fumes, most acids, salt spray, and weathering. Available in 1 and 5-gal cans, paint conforms to government and industrial specifications for heat-resistant coatings. **Speco Inc.**, 7308 Associate Ave., Cleveland 9, Ohio.

Circle 635 on Page 19

Miniature Indicator Light

is visual identification unit



New visual identification light is 1.6 in. long with a back-lighted rectangular plastic head measuring $\frac{5}{8}$ x 15/16 in. Two $\frac{1}{2}$ in. or three smaller digits or letters can be accommodated easily on the colored plastic face, available in a variety of colors. Midget flanged bulb used is designed for an electrical system of 6, 12, or 28 v. Lighting units provide maximum identification at greater distances than nonilluminated or front-lighted identification tabs. **Glar-Ban Corp.**, 108 Glar-Ban Bldg., 3807 Harlem Rd., Buffalo 15, N. Y.

Circle 636 on Page 19

Filter-Regulator-Lubricator

for limited-space uses

Compact, miniature, air-line filter-regulator-lubricated assembly is designed for applications where space is limited or low flow requirements are a factor. Unit is available in $\frac{1}{8}$ and $\frac{1}{4}$-in. sizes, with maximum pressure at 150 psi. Filter features a 20-micron, porous-bronze element; lubricator provides excellent lubrication at flow rates from 0.2 to 15 cfm without excessive pressure drop. Both fill plug and oil-feed adjustments are interchangeable front to rear. **Industrial Div., Watts Regulator Co.**, Lawrence, Mass.

Circle 637 on Page 19

Magnet Wire

operates in excess of 260 C

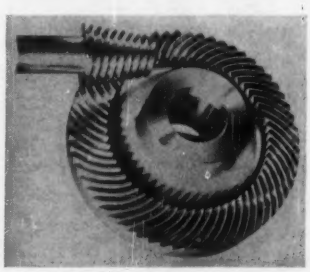
High-temperature, high-abrasion-resistant magnet wire, employing a cross-linked polymer for insulation, is called Hitemp FX. In addition to operating continuously at temperatures in excess of 260 C, wire has excellent abrasion resistance. Tough, thin insulation overcomes the problems of poor abrasion, cold flow, and resistance to impregnating and potting encountered in other high-temperature insulations. Wire is available in sizes 14 to 44 in single thickness. **Hitemp Wires Co., Div., Simplex Wire & Cable Co.**, Westbury, N. Y.

Circle 638 on Page 19

Precision Spiroid Gears

in $\frac{1}{8}$, 3/16, and $\frac{1}{4}$-in. shaft sizes

Precision Spiroid gears in $\frac{1}{8}$, 3/16,



Important New Book for Anyone Interested in Material Specifications

Contains 68 pages of engineering facts about Meehanite®.

This technical book has been prepared for designers, engineers and purchasing executives who strive to improve product performance and reduce manufacturing costs. It presents the physical properties of each of the 26 types of Meehanite metal available and is jam-packed with data that makes it easier for the materials engineer to evaluate and specify the most suitable metal for his casting application. Included are heat treatment and machining data and numerous photographs of typical applications. For your free single copy see one of the Meehanite foundries listed below or write *Meehanite Metal Corporation, 714 North Avenue, New Rochelle, New York.*

MEEHANITE METAL

The American Laundry Machinery Co., Rochester, N. Y.
Atlas Foundry Co., Detroit, Mich.
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Barnett Foundry & Machine Co., Irvington, N. J.
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Centrifugally Cast Products Div., The Shenango Furnace Co., Dover, Ohio
Crawford & Doherty Foundry Co., Portland, Ore.
Dayton Casting Co., Dayton, Ohio
Empire Foundry Co., Tulsa, Okla.
Florence Pipe Foundry & Machine Co., Florence, N. J.
Fulton Foundry & Machines Co., Inc., Cleveland, Ohio
General Foundry & Mfg., Flint, Mich.
Georgia Iron Works, Augusta, Ga.
Greeniee Foundries, Inc., Chicago, Ill.
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Kanawha Manufacturing Co., Charleston, W. Va.
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Lincoln Foundry Corp., Los Angeles, Calif.
Love Brothers — Pyott Foundry & Machine Div. Mueller Ind. Inc., Aurora, Ill.
Oil City Iron Works, Corsicana, Texas
Palmyra Foundry Co., Inc., Palmyra, N. J.
The Henry Perkins Co., Bridgewater, Mass.
Pohlman Foundry Co., Inc., Buffalo, N. Y.
Rosedale Foundry & Machine Co., Pittsburgh, Pa.
Ross-Meehan Foundries, Chattanooga, Tenn.
Sonith Foundries of FMC, Indianapolis, Ind.
Standard Foundry Co., Worcester, Mass.
The Stearns-Roger Mfg. Co., Denver, Colo.
Vulcan Foundry Co., Oakland, Calif.
Washington Iron Works, Seattle, Wash.
Dorr-Oliver-Long, Ltd., Orillia, Ontario
Hartley Foundry Div., London Concrete Machinery Co., Ltd., Brantford, Ontario
Otis Elevator Co., Ltd., Hamilton, Ontario

MEEHANITE METAL CORPORATION, NEW ROCHELLE, NEW YORK

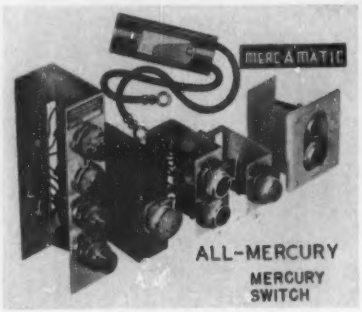
and ¼-in. shaft sizes offer the designer of small package assemblies added advantages in backlash control, shock strength, noise level, and accuracy in high-ratio, right-angle gearing applications. Multitooth-contact design provides inherent precision control unobtainable with other forms of low-contact-ratio gearing. **PIC Design Corp.**, 477 Atlantic Ave., East Rockaway, L. I., N. Y.

Circle 639 on Page 19

Pushbutton Stations

are mercury-activated units

Merc-Amatic mercury pushbutton stations are available in multiunit combinations with indicating light assemblies for panelboard, as well as individual station installations. All of the mercury-actuated switching devices employ high current-interrupting capacity, sealed-mercury contactors with capacities to 50 amp. Contacts are dust, dirt, and moisture-proof, compatible with safety requirements for hazardous applications. **Tigerman Engineering Co.**, 4332 N. Western Ave., Chicago 18, Ill.

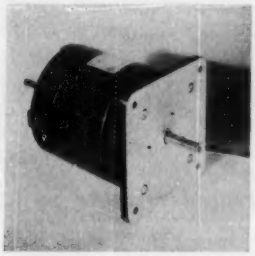


Circle 640 on Page 19

AC Motors

in 4500 frame series

New 4500 frame series of ac motors have an outside diameter of 5⅜ in. and are available with single, two, or three-phase inputs, 26 to 230 v, and with frequencies from 25 to 400 cps. Series includes units which provide outputs to 1½ hp as induction motors, up to 300 oz-in. stall torque as torque motors, and from 1/200 to ⅓ hp as hysteresis synchronous motors. They



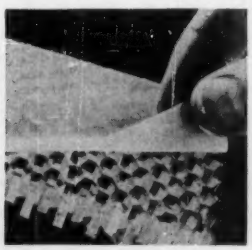
can also be wound for single, dual, three, and four-speed operation. Standard ambient temperature range is −55 to +71 C. Motors can be supplied with round or square flange mountings and bases, and with single or double shaft extensions. **IMC Magnetics Corp.**, 6058 Walker Ave., Maywood, Calif.

Circle 641 on Page 19

Film Adhesive

for honeycomb sandwich construction

High-strength, supported, epoxy-resin film adhesive combines the advantages of film adhesives with the excellent self-filleting properties of epoxy adhesives. Designated Scotch-Weld AF-106, it is used to bond metal and paper honeycomb cores to metal facings in honeycomb sandwich construction. Adhesive provides uniform adhesive thickness throughout the assembly, controlled confinement of adhesive to the immediate bonding area, clean bonding operations, and simple application procedures. Material is available in varying widths and thicknesses and can be cut to fit the honeycomb assembly. Adhesive provides metal-to-metal bonds with shear strengths of over 2000 psi at 75 F, maintains high strength over a service temperature range of −67 to +300 F, and has excellent peel strength. It has high creep resistance under constant stress, exceptional adhesion to metals and plastics, and excellent resistance to



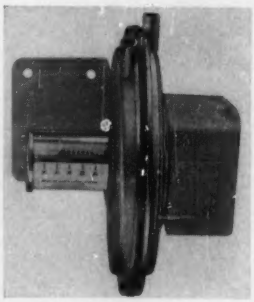
water, 20-per cent salt spray, hydraulic oil, and aromatic fuel. **Adhesives, Coatings, and Sealers Div., Minnesota Mining & Mfg. Co.,** 900 Bush Ave., St. Paul, Minn.

Circle 642 on Page 19

Differential Pressure Switch

for extreme low-pressure use

Series 1630 differential pressure switch provides accurate, reliable control in pressure ranges too low for conventional switches. Dead band is unusually small. Repetitive accuracy is within 1 per cent, and



there is virtually no error due to drift or hysteresis. Switch is suitable for such applications as liquid-level controls, induced draft interlocks, exhaust hoods, dust-collection systems, and air filters. Pressure set point is easily visible on an accurate scale marked in inches of water. Calibration adjustments can be sealed or safety wired, making the switch tamperproof. **F. W. Dwyer Mfg. Co.,** Dept. MD-1, P. O. Box 373, Michigan City, Ind.

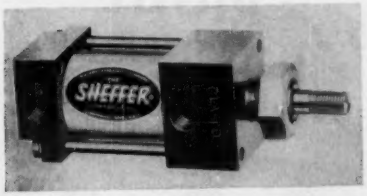
Circle 643 on Page 19

Air Cylinder

has short over-all length and is light in weight

Improved stud-mount, 1⅛-in. bore, clamp-type air cylinder for 150 psi air or 250 psi hydraulic service is available as a double-acting or spring-return unit. Cylinder is 1½ in. square, with short over-all length. It is extremely light in weight through the use of sturdy machined aluminum bar-stock heads. Sintered-bronze bushing in rod head gives improved bearing surface for stainless-steel piston rod. Rod seals are Block-Vee type for

Circle 475 on Page 19



more positive seal with lower friction factor. Ports are ⅛-in. dry seal pipe thread. Sheffer Corp., 326 W. Wyoming Ave., Cincinnati 15, Ohio.

Circle 644 on Page 19

Antibacklash Gears

in 32, 48, 64, 72, 96, and 120 diametral pitches

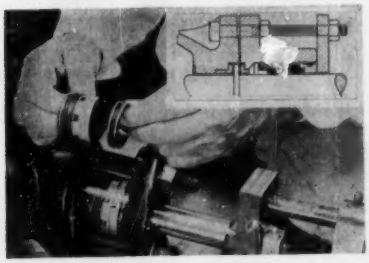
Appco precision antibacklash gears meet AGMA specifications. Various predetermined tooth loadings for any specific antibacklash gear can be chosen, providing custom gear design at stock gear prices. Gears are available in AGMA Precision Classes 1 and 2, in 32, 48, 64, 72, 96, and 120 diametral pitches. Two face-width configurations are available in both aluminum and stainless steel. Each gear is mounted on a shipping tray and sealed in Mylar plastic to avoid contamination by dust, dirt, or fingerprint corrosion. Aluminum gears are available in seven plating options. Atlas Precision Products Co., Dept. A, 3801 Castor Ave., Philadelphia 24, Pa.

Circle 645 on Page 19

Valve Stem Seal

reduces friction and eliminates leakage

End face seal for nonrising valve stems greatly reduces the amount of friction normal to other sealing methods and, at the same time, eliminates all leakage. It is suited for motorized and hand-operated valves in a wide range of services.



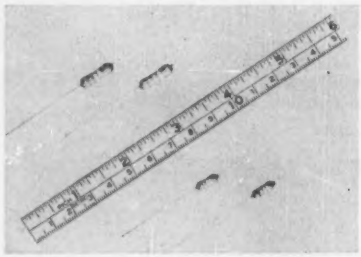
It is highly recommended for valve service in tankers, refineries, and petrochemical plants. **Crane Packing Co.**, Dept. MD-1, 6400 Oakton St., Morton Grove, Ill.

Circle 646 on Page 19

Film Resistors

exceed requirements of MIL-R-11C

New 1 and ½-w high-quality film resistors far exceed requirements of MIL-R-11C. C-20 and C-32 units have a silicone coating that withstands cleaning solvents used by printed-circuit manufacturers. Typical operating characteristics include: Derating—full load at 70 C ambient to zero power at 150 C; load life—change in resistance of 1 to 1½ per cent after 1000 hr operation at 70 C; moisture resistance—change in ohmic value of 0.3 per cent; temperature coefficient—±150 ppm per deg C between −55 and +150 C. Resistance ranges are 56 to 150,000 ohms for the C-20 and 56 to 470,000 ohms for the C-32. **Electronic Components Div., Corning Glass Works**, Corning, N. Y.

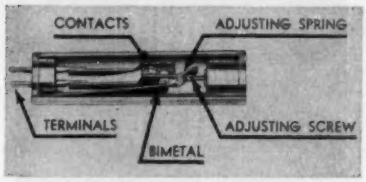


Circle 647 on Page 19

Miniature Thermostat

provides close control and long, stable life

Model 292 miniature thermostat, 0.317 in. in diam. and 1.325 in. long, provides close control and long, dependable life in crystal ovens, oscillator compartments, and computers. Thermostat is hermetically sealed to hold control temperature to 1½ deg C for over 500,000 operations with a resistive load of ½ amp at 26 v dc. Unit handles loads to ½ amp at 115 v, 60 cycles, ac. Because of its small size and the low mass of its moving parts,



it is shock and vibration resistant, making it ideal for use in military equipment and electronic apparatus subject to rough treatment. **Instrument Div., McGraw Edison Co., Thomas A. Edison Industries,** 61 Alden St., West Orange, N. J.

Circle 648 on Page 19

Adhesive System

for temperatures from −100 to +500 F

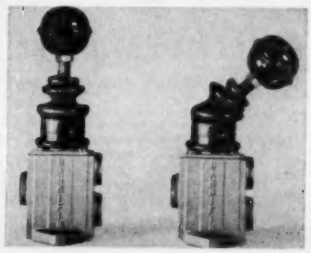
Improved adhesive system for bonding silicone rubber to itself or silicone rubber to glass, Dacron and nylon fabrics is also used for bonding silicone rubber to metal, plastics, glass, and ceramics with the aid of a metal primer. Cohrlastic C-251 is a silicone-rubber, thermal-curing cement with an effective temperature range from −100 to +500 F. It shows bond strengths from 8 to 15 psi peel strength, depending upon the formulation of the silicone rubber to be cemented. Material cures under heat and pressure to form a tough, flexible bond. **Connecticut Hard Rubber Co.,** 47 East St., New Haven 9, Conn.

Circle 649 on Page 19

Synthetic Dust Boot

keeps dirt from hand valves

Snug-fitting, wear-resistant synthetic boot provides maximum protection for hand-valve actuating mechanisms against dirt and moisture. Boots keep dirt out of the hand toggle head assembly without hampering normal valve operation. Boots



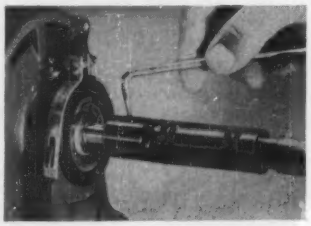
can be installed on Hannifin C and CC hand valves now in use, or are offered as an optional feature on new valves. Hannifin Co., Div., Parker-Hannifin Corp., 501 S. Wolf Rd., Des Plaines, Ill.

Circle 650 on Page 19

Flexible Shafts

standard units are available from stock

Complete flexible shaft packages—shaft, neoprene-covered casing, standardized coupling—are available off the shelf. Complete stock in shaft sizes from 0.150 to 0.500 in. is maintained in standard lengths, ready to attach to mating spindles. Shafts are suitable for prototype or medium-volume requirements, either



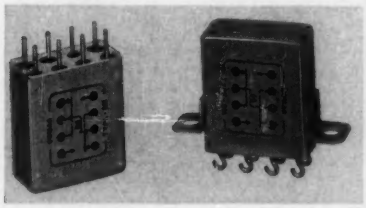
for power transmission or remote control, and can also be utilized to simplify existing equipment. They are designed for high speed and continuous operation, and are usable in either rotational direction. Flexible drive shafts eliminate belts, gears, and universals, and operate with no shock or vibration. S. S. White Industrial Div., Dept. PR, 10 E. 40th St., New York 16, N. Y.

Circle 651 on Page 19

Subminiature Relay

for continuous use in −65 C temperature

Subminiature relay, Type SM-2, is hermetically sealed with 0.200-in. centers terminal configuration and 3-amp contact rating. Relay is less than 1 in. long and weighs less than ¾ oz. Designed for continuous use in the −65 C temperature range, it meets MIL-R-25018 and MIL-R-5757C specifications, and has a life expectancy of 100,000 operations minimum at rated load. Relay withstands severe vibration, heavy shock, and high temperature while maintaining fast, sensitive op-



eration. Unit is especially suited for use in control systems, computers, aircraft, missiles, and other applications requiring miniature size and dependable performance. Comar Electric Co., 3349 W. Addison St., Chicago 18, Ill.

Circle 652 on Page 19

Induction Motor

is high-performance, totally enclosed unit

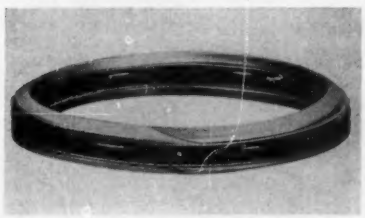
DE-30-14 induction motor is a high-performance unit designed specifically to drive a 20-in. fan in military ground-support equipment, but readily adaptable to other military and commercial applications. Features incorporated include a specialized gear box, oil-filled gear case, and compact construction. Totally enclosed motor has a horsepower rating of 0.325 hp, and speed of 5600/1725 rpm. Kearfott Div., General Precision Inc., 1150 McBride Ave., Little Falls, N. J.

Circle 653 on Page 19

Seal-Ring Assembly

seals off large differential pressures

New seal-ring assembly seals off large differential pressures in applications in which ordinary O-ring seals extrude and fail. Unit can seal off pressure greater than 50,000 psi. It is supplied for all ranges



of O-rings in diameters from less than ¼-in. to many feet. Bowen Itco Inc., 2429 Crockett, Houston, Tex.

Circle 654 on Page 19

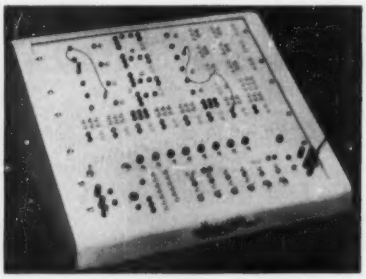
ENGINEERING DEPARTMENT

EQUIPMENT

Logic Trainer

demonstrates basic circuit operation

TDC digital logic trainer is an easy-to-use instruction and demonstration tool for training in digital circuit operation, logic design breadboarding, and testing digital circuits. It effectively demonstrates basic circuit operation, as well as effects of loading and timing on circuit and network performance. Coupling of various circuit types for control, storage, timing, and logic can be understood easily. Front panel con-



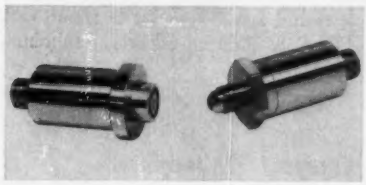
tains 50 prewired S100 digital circuits, with logic symbols for each clearly identifying input-output connections and their function. All connections are made on the large patch-board front panel with pin-jack jumpers. Input-output jacks are color coded for direct observation of terminal function, and circuits, switches, and controls are clearly marked for instruction in use of the trainer. **Components Div., Epsco Inc.**, 275 Massachusetts Ave., Cambridge 39, Mass.

Circle 655 on Page 19

Pressure Transducers

for temperatures from −100 to +600 F

Models 538B and 539B transducers feature precycled, prestabilized, standardized operation in temperature environments from −100 to +600 F. They operate in these



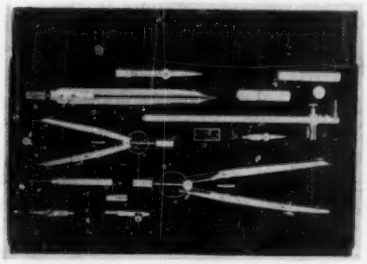
temperatures during shocks in excess of 100 g for 11 millisec in any direction. Performance is standardized to such close tolerances that models covering identical full-scale ranges can be interchanged without recalibrating the measuring system. Miniature units are of the bonded strain-gage type. They are identical except for pressure fitting, the 538B having a flush-mounting diaphragm and the 539B a threaded fitting for ¼-in. flared tubing. Each has a welded stainless-steel diaphragm to withstand corrosive and conductive media. Recommended excitation voltage for the four-active-arm resistive Wheatstone bridge is 10 ac or dc. Each unit is approximately 2⅝ in. long by 1⅛ in. diam; weight is 3.5 oz. **Ascop Div., Electro-Mechanical Research Inc.**, Sarasota, Fla.

Circle 656 on Page 19

Drawing Instrument Set

is medium priced for student or professional use

Mark II 13-piece drawing instrument set consists of nickel-silver instruments of a new design, furnished in a green leatherette case lined with green velvet. Instruments include a 6½-in. central-thumbscrew bow compass with fast opening and closing action; 5¾-in. extension bar; a 4½-in. bow compass; 6-in. divider; 5½-in. ruling pen with stainless-steel blades of cross-hinge type; pen handle; leads, spare parts, and needle points; center pin; screw driver. Set is medium-priced for student or pro-



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fessional use. Keuffel & Esser Co., Third & Adams Streets, Hoboken, N. J.

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Compact Whiteprinter

has variable printing-speed range

Copymaster compact table or wall mounted, 44-in. whiteprinter has a variable printing-speed range to 10 fpm controlled by a simple knob with full-reverse feature. Wide feed table simplifies print feed and return. Horizontally mounted, self-sealing chamber processes several prints simultaneously. Unit produces sharp prints quickly from any translucent material, makes excellent intermediates and sepias. Three easily replaceable, black-light fluorescent lamps provide the light source. Unit plugs into a standard electrical outlet. Copymation Inc., 5650 N. Western Ave., Chicago 45, Ill.

Circle 658 on Page 19

Drawing Boards

have aluminum edges to resist warping

Series 710-M drawing boards are available in 12 x 17, 16 x 21, 18 x 24, 20 x 26, and 23 x 31-in. sizes. Boards are of select lumber, and incorporate aluminum edges for high accuracy in drawing with a T-square, and high resistance to warping. Anco Wood Specialties Inc., Glendale 27, L. I., N. Y.

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THE ENGINEER'S

Library

Recent Books

International Dictionary of Applied Mathematics. *1173 pages, 7½ by 10¼ in., clothbound; published by D. Van Nostrand Co. Inc., 120 Alexander St., Princeton, N. J.; available from* MACHINE DESIGN, *$25.00 per copy postpaid.*

Terms and methods of application of mathematics to 32 fields of science and engineering are covered. More than 8000 entries are presented. All basic definitions and methods from pure mathematics, as well as from science and engineering, are included. Indexes in German, Russian, French, and Spanish are listed with their English equivalents.

Numerical analysis is developed to emphasize methods used in programing problems for solution by digital computers. Other recent approaches emphasized include application of topology in definitions of electrical networks, extensive use of dynamical analogies in solving problems in mechanics and acoustics, tensor analysis, and quantum mechanics.

Boundary Layer Theory. *By Hermann Schlichting; translated from German by J. Kestin; 647 pages, 6½ by 9½ in., clothbound; published by McGraw-Hill Book Co. Inc., 330 West 42nd St., New York 36, N. Y.; available from* MACHINE DESIGN, *$16.50 per copy postpaid.*

Fluid mechanics of boundary layers is thoroughly discussed. Compressible, incompressible, and thermal boundary layers are treated. Laminar, transition, and turbulent flows are analyzed.

This fourth edition contains new and revised material, particularly in treatment of transition, nonsteady boundary layers, thermal boundary layers, and suction. All recent advances in boundary-layer theory are considered.

Chipless Machining. *By Charles H. Wick; 502 pages, 6¼ by 9¼ in., clothbound; published by The Industrial Press,*

93 Worth St., New York 13, N. Y.; available from MACHINE DESIGN, *$10.00 per copy postpaid.*

Methods of moving metal rather than removing it are described. Cold heading, rolling, spinning, swaging, extruding, and high-energy-rate forming are covered.

Discussion includes processes for cold-working steel, essential steps in making parts, design of equipment and tooling, and typical applications. Data are included on newer processes of spline-and-gear rolling, radial forging, power spinning, and explosive forming.

Government Publications

NASA Technical Notes. Copies of publications listed below are available from Office of Technical Services, U. S. Dept. of Commerce, Washington 25, D. C.

TN D-447. Investigation of Problems Associated with the Use of Alloyed Molybdenum Sheet in Structures at Elevated Temperatures. By Eldon E. Mathauser, Bland A. Stein, and Donald R. Rummler, Langley Research Center; 60 pages, 7¾ by 10¼ in., paperbound, side-stapled; $1.50 per copy.

Capabilities and limitations of thin Mo-0.5 Ti molybdenum-alloy sheet for structural applications at high temperatures were investigated. Evaluation tests at temperatures ranging from room temperature to 3000 F were conducted on resistance-welded corrugated-core sandwiches with a W-2 coating, and on coated oxidation and tensile specimens.

TN D-508. Analog Techniques for Measuring the Frequency Response of Linear Physical Systems Excited by Frequency-Sweep Inputs. By Wilmer H. Reed III, Albert W. Hall, and Lawrence E. Barker Jr., Langley Research Center; 59 pages, 7¾ by 10¼ in., paperbound, side-stapled; $1.50 per copy.

Data-reduction methods using general-purpose analog computing equipment and compatible testing techniques for determining frequency response of linear physical systems are examined. Relative merits of sinusoidal, slow sweep, and transient-type rapid-sweep forcing functions are discussed. Applications that relate to dynamic-response tests of aeroelastic systems are presented.

OTS Technical Reports. Copies of reports listed below are available from Office of Technical Services, U. S. Dept. of Commerce, Washington 25, D. C.

PB 161488. Investigation of Creep Buckling of Columns and Plates—Part 1: Elevated Temperature Properties of the Test Material Ti-7Al-4Mo Titanium Alloy. By Ralph Papirno and George Gerard, New York University; 27 pages, 8½ by 10¾ in., paperbound, stapled; $1.00 per copy.

Tension and compression tests were conducted with the alloy in both the annealed and heat-treated conditions. A new technique for collection of compression creep data from sheet specimens was developed. Short-time tests were conducted at room temperature, 750F, 850F, and 950F. Compression creep data were collected at 850F and 950F.

PB 161532. The Lower Critical Stress for Delayed Failure. By E. A. Steigerwald, F. W. Schaller, and A. R. Troiano, all from Case Institute of Technology; 30 pages, 8½ by 10¾ in., paperbound, stapled; $1.00 per copy.

Lower critical stress was defined as the minimum stress necessary to produce the critical amount of hydrogen segregation for crack initiation. A distribution law involving hydrogen concentration, applied stress, and temperature was assumed. On the basis of this law, observed changes in lower critical stress as a function of notch acuity, yield strength, temperature, and initial hydrogen content were explained for a range of these variables.

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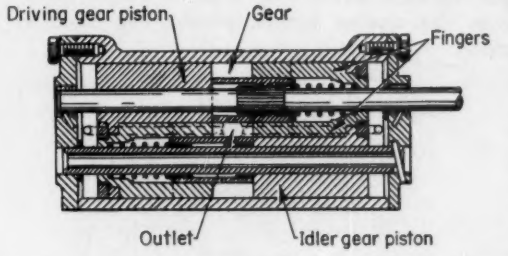
Patents

Variable-Flow Gear Pump

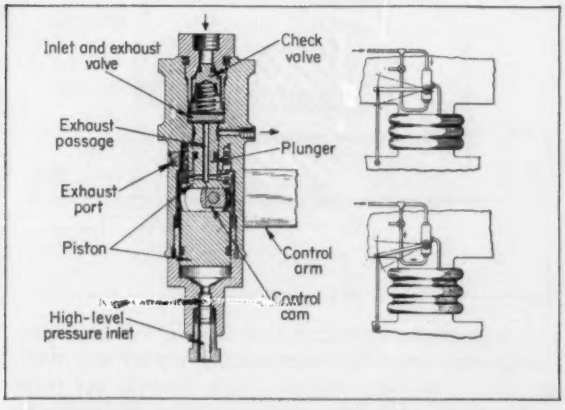
Any variation from a predetermined outlet pressure in a gear pump repositions the meshing gear rotors relative to each other, giving an instantaneous change in the effective displacement of the pump. This action provides a constant pressure regardless of volumetric requirements or rotational speed. Separate positioning



pistons are provided for each gear rotor. These pistons are acted upon by the outlet pressure. Plugging of the space between the unmeshed portion of the gear teeth is accomplished by means of sliding fingers. Springs prevent complete disengagement of the gears. *Patent 2,955,541 assigned to Engineering & Research Lab. Service Co., Indianapolis, Ind., by Cecil L. Moore.*

Adjustable Hydraulic-Suspension Leveling Valve

Control valve for an air-spring suspension system maintains a vehicle frame at either of two levels, regardless of load changes. With the suspension set at either high or low position, a counterclockwise move-

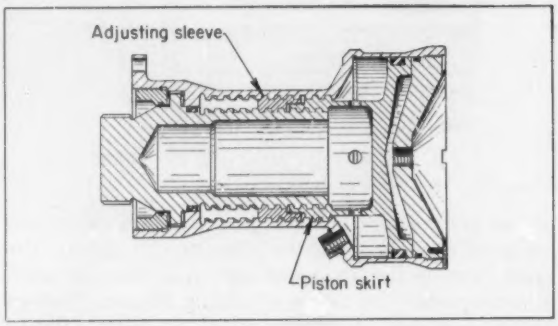


ment of the control arm raises the piston and plunger, unseating the inlet and exhaust valve and allowing pressurized air into the spring until the control arm is

again centered. Movement of the arm in a clockwise direction lowers the piston and plunger, allowing air to escape through the exhaust passages in the center of the plunger. To set the suspension at high position, a manual shutoff valve is opened, diverting the supply pressure to the spring through the port at the bottom of the valve. As the spring is inflated, pressure on the base of the piston causes the entire valve assembly to move up, while the control arm is repositioned so that it is at an angle to the horizontal in its neutral position. *Patent 2,959,426 assigned to Bendix-Westinghouse Automotive Air Brake Co., Elyria, Ohio, by Darold A. Augustin.*

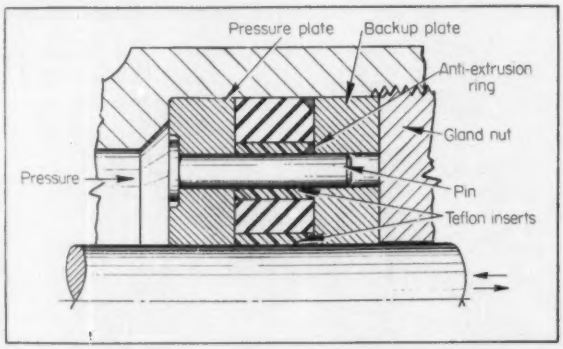
Antibacklash Actuator

A threaded sleeve takes up the play between the helical splines in a rotary actuator. The sleeve eliminates backlash by causing a slight misalignment between the mating splines, putting the assembly in tension.



Adjustment is carried out before the piston is placed in the cylinder. When the backlash has been eliminated, the unit is assembled. *Patent 2,959,064 assigned to General Motors Corp., Detroit, Mich., by Howard M. Geyer and Robert C. Helke.*

High-Pressure Fluid Seal

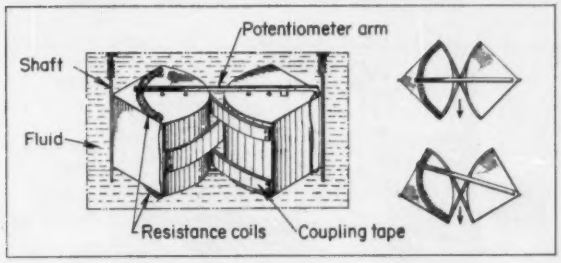


A high-pressure packing unit used to seal a reciprocating shaft assembly automatically repairs any damage to its sealing surfaces. These surfaces are made of a material that flows under operating pressures and temperatures. An antiextrusion ring prevents the material from flowing between the shaft, or pins, and the backup plate. Pins are arranged radially in

the pressure plates to provide a differential area between the pressure plate and the seal, so that the pressure tending to seal the unit is always greater than the chamber pressure acting on the pressure plate. *Patent 2,960,332 assigned to Cleveland Pneumatic Industries Inc., Cleveland, Ohio, by Arthur L Lindow and Richard A. Graff.*

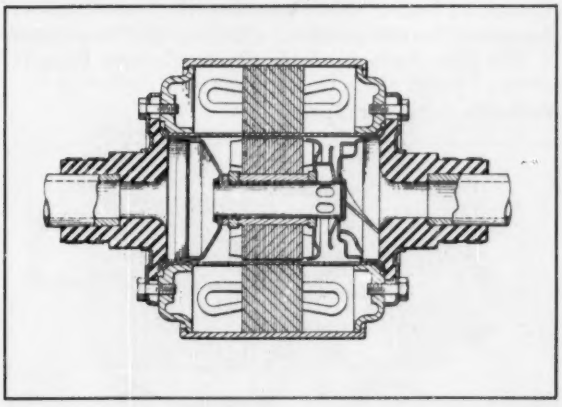
Dual-Mass Linear Accelerometer

A linear accelerometer uses a pair of floating masses coupled in such a way that angular accelerations are canceled out. The masses rotate about parallel axes on shafts running in jeweled bearings. To eliminate crosstalk, backlash, and bearing friction, the masses are mounted in a liquid whose specific gravity is equal to that of the masses. Linear acceleration of the casing causes rotation of the masses about their



axes. The masses are coupled by means of flexible, nonextensible tapes. This system assures that the masses can rotate only in opposite directions, canceling out any angular accelerations, which tend to cause the masses to rotate in like directions. A voltmeter is used in conjunction with a moving-arm potentiometer to indicate accelerations. *Patent 2,959,057 assigned to Physical Measurements Corp. by Daniel E. Winker.*

Vibration-Isolating Pump Fitting



A pair of fluid-tight flexible fittings on opposite ends of a motor-driven pump reduce noise and vibration transmitted to the attached fluid lines. The fittings are made of a moldable elastomer capable of withstanding 250 F, have low vibration transmissibility characteristics, and are strong enough to withstand hydraulic

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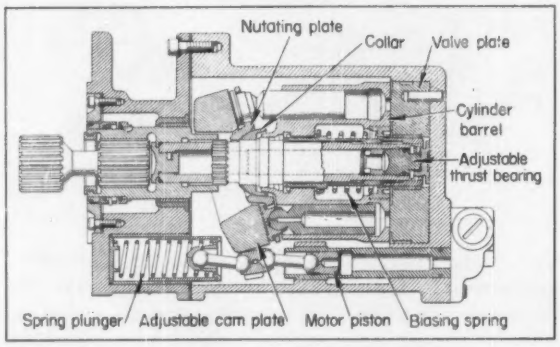
surges without ballooning. Capable of supporting the motor without reinforcement, they have a natural frequency which is substantially lower than the rotational speed of the pump. The fittings damp vibrations by absorbing them as shearing forces. They are retained by annular ring plates bolted to the pump casing. Steel bands secure them to the fluid lines. *Patent 2,958,296 assigned to The Fostoria Corp., Fostoria, Ohio, by Richard H. Carter.*

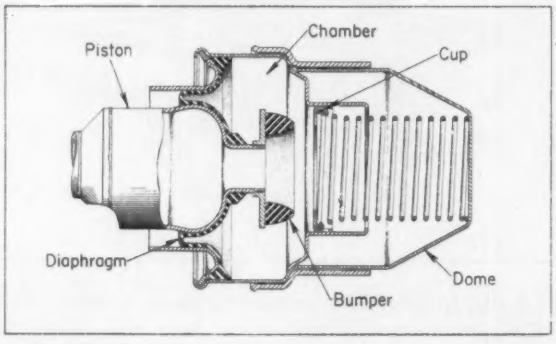
High-Speed Axial Piston Pump

Inertia loads which ordinarily tend to separate the pistons from the actuating cam are transmitted directly to the pump casing in an axial piston pump. The resulting absence of hammering allows operation of the pump at high speeds. When the pump has been assembled, a tool is inserted into the inner pump shaft, and the threaded thrust bearing is adjusted until the collar is held firmly between the shaft shoulder and



the nutating plate. Any inertia loads which would ordinarily react on the biasing spring are transmitted directly to the pump casing. Thus, the biasing spring has only to maintain the proper contact pressure between the cylinder barrel and valve plate. The cam plate is connected by a universal joint to a spring plunger and motor piston assembly which serve to vary the plate's angular position. *Patent 2,953,099 assigned to The New York Air Brake Co. by Tadeusz Budzich.*

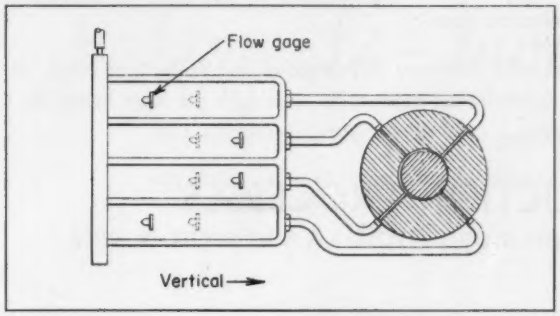
Variable-Rate Air Spring



A dual-volume arrangement provides two ranges of rebound damping in an air spring assembly. Under normal rebound conditions, the air in both the dome

and the chamber is compressed by the piston and diaphragm assembly. When the normal rebound rate is exceeded, the bumper, made of a suitable elastomer, contacts the bottom of the cup, forcing it upwards. The resultant small chamber volume produces a progressively greater damping action, while additional damping is obtained from compression of the air in the dome and piston by the working surface of the piston. *Patent 2,956,797 assigned to General Motors Corp., Detroit, Mich., by Von D. Polhemus.*

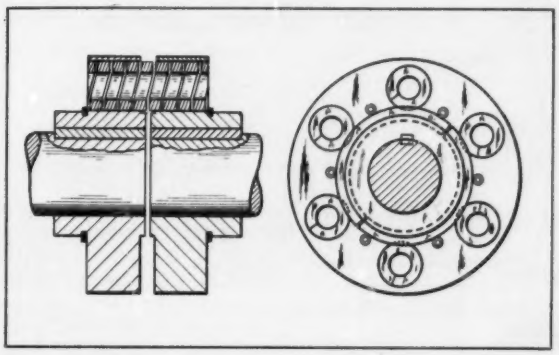
Adjustable Rotary-Shaft Bearing



Fluid pressure is used to position a rotary shaft in its bearing. After the bearing is assembled, a fluid—preferably air—is forced under pressure through the space between the shaft and the bearing surface. The fluid passages are connected to separate pressure sources, which can be adjusted so that flow through each of the passages is either equal, indicating that the shaft is centered in the bearing, or proportioned to give a desired shaft position. *Patent 2,955,350 assigned to General Electric Co. by Emmett G. Gardiner.*

Flexible Shaft Coupling

A simple shaft coupling uses springs to absorb starting loads and to take up misalignment between mating parts. Helical springs extend through a series of matching positioning retainers in both hubs. The springs



are made of spring wire of square cross section to provide maximum load-carrying capacity and to assure a large bearing area in the retainers. *Patent 2,959,944 assigned to The Atomic Manufacturing Co., East Pittsburgh, Pa., by Raymond G. Brownstein.*

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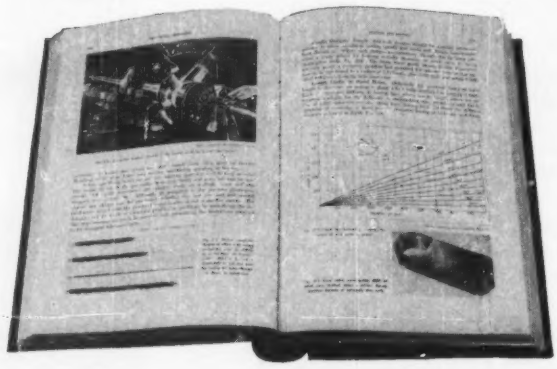

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Volume 32—January to December

The September 29 issue was published in two sections identified here as Sept. 29—1 and Sept. 29—2. Section 2 is *The Fasteners Book*.

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MACHINE DESIGN is sent at no cost to management, design and engineering personnel whose work involves design engineering of machines, appliances, electrical and mechanical equipment, in U. S. and Canadian companies employing 20 or more people. Copies are sent on the basis of one for each group of four or five readers. Consulting and industrial engineering firms, research institutions and U. S. government installations, performing design engineering of products are also eligible.

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BPA NEP

backtalk——

—An Important Denouncement

"There is a grievous error on Page 34 of the November 24 issue," says the letter from Milton F. Lunch, "attributing a quoted statement by the American Federation of Technical Engineers to me and transferring my employment from NSPE to AFTE. The quoted statement by AFTE is correct, but I did not say it, and, in fact, have written reams of letters, documents, etc., denying and denouncing it as untrue.

"Will you kindly advise your readers, in the words of a maligned congressman of some years ago, 'I deny the allegation and denounce the alligator.'"

We do hereby kindly advise our readers that Mr. Lunch, who serves as Legislative Counsel for the National Society of Professional Engineers, does not believe that "the engineer is more closely akin to the machinist at his lathe and the production worker on the line." These phrases are part of the quotation attributed correctly to the American Federation of Technical Engineers but incorrectly to Mr. Lunch in Part 2 of our series "You and the Unions."

Next, we wish to pass the buck, or alligator, to the boys at Harvard who prepared the research report, "Engineers and Unions," on which our articles were based. They prefaced the quotation in question with "AFTE declared" then credited it via footnote to a talk by Mr. Lunch. We see by his letter that the quotation was part of Mr. Lunch's talk, but that he was quoting AFTE.

Confused? Good, so were we. We're sorry that we shifted Mr. Lunch's allegiance and are glad to get him back where he belongs.

—Where To Sell It

Worried about the high volume of imports in relation to exports by the United States? If you are, some comforting literature is the listing of possible new or expanded export market opportunities compiled by the Bureau of Foreign Commerce of our Dept. of Commerce. Curled up in front of the fire scanning these lists the other evening, we were impressed, not only with the number and variety of items wanted in other countries, but also with the implications of these wants.

For instance, people in many of the warm corners of the earth are tired of being hot. Air conditioners are wanted in Greece, Iran, Kuwait, Mexico, Pakistan, Trinidad, Burma, Ecuador, Angola, Austria, Indonesia, Jordan, Malaya, and Sudan. Some Sudanese will be satisfied with electric fans, but the Burmese also want automobile air conditioners.

Agricultural machinery is needed in about 40 of the 60 potential market areas listed; aircraft, in six. Electrical equipment and scientific instruments are in fairly heavy demand, as are all types of motor vehicles.

Incidentally, we suspect a trend in the thirst of Viet-Nam. Among the needs of that country are industrial air conditioners, aluminum sheet and circles, pumps and other hydraulic equipment, malt and hops. Could it be the Viet-Namese are forsaking their teapots for the handy six-pack?

—In Days of Auld 1960

This issue of MACHINE DESIGN, as you know, is the last one for 1960. If you have given all the magazines the attention they deserve, you have admired more than two dozen examples of George Farnsworth's cover art; turned some 7000 pages (1200 of them devoted to 250 feature articles); and placed the *Fasteners Book* in a safe, handy place. You have also kept up-to-date with our Engineering News, Scanning the Field for Ideas, Design in Action, Design Abstracts, and New Parts pages.

Only our uncommon modesty keeps us from boasting about the plans we have for 1961, but we can promise 26 equally informative regular issues, plus four handbooks. The first of 1961's books will be published in January.

And before you close the cover on Vol. 32, No. 26, we would like to wish you a happy, prosperous, and technically literate New Year.

Advertising Index

Circle 508 on Page 19

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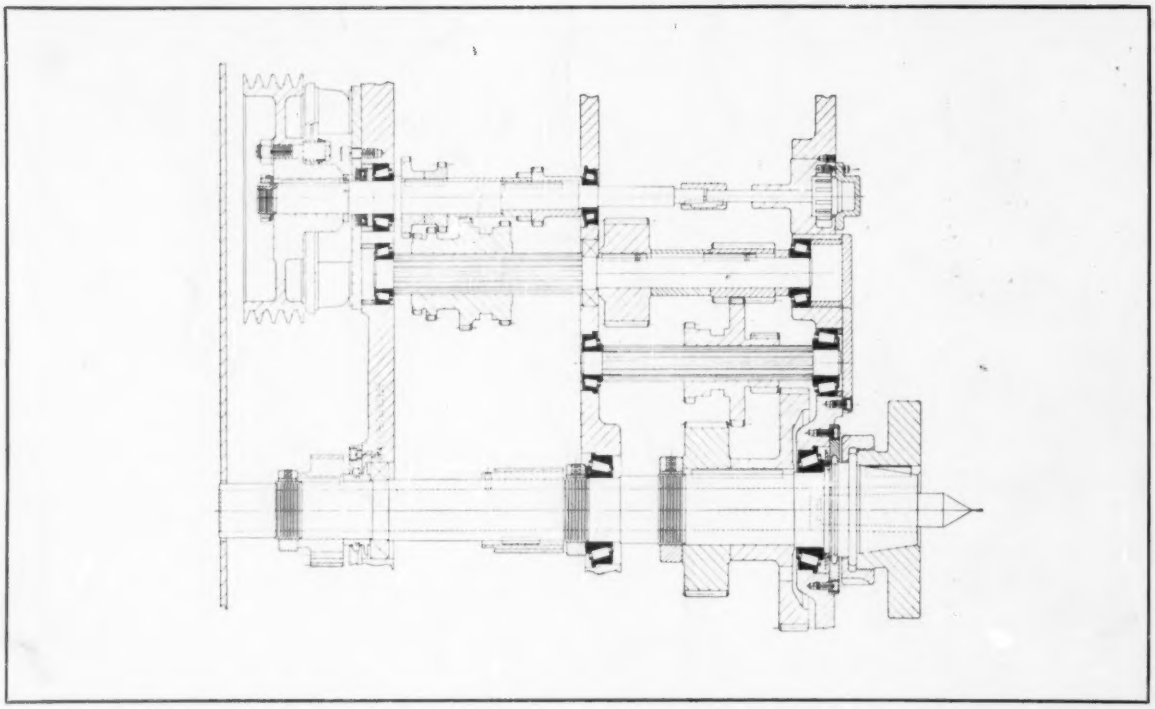
Circle 402 on Page 19

LeBLOND lathe obtains super spindle-runout of less than .000025″ with Timken® "00" bearings



To raise the already great precision of its 15″ Dual-Drive lathe to a special new high for a customer, LeBlond had to meet this requirement: spherocity of the part to be turned—a beryllium gyro float assembly—had to be concentric with its two major axes within .0005″ total indicated runout. Diameter of the sphere: 1.8750″.

To assure this, LeBlond engineers specified Timken® super-precision "00" tapered roller bearings held to .000025″ assembled runout for the spindle—one-third the normal runout tolerance for these bearings. Timken bearings were also used on the intermediate, back and feed shafts of the drive. The assembled spindle runout (total indicator reading) was actually less than .000025″.

Producing super-precision bearings like this is typical of Timken Company service. The kind of service that developed Timken "00" bearings to meet industry's needs for ever-greater precision. It's another example of the Timken Company's leadership in tapered roller bearing design and manufacture.

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